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ARTILLERY SERVICE OF THE SOCIETE DES FORGES ET CHANTIERS.

THE Societe des Forges et Chantiers of the Mediterranean is the largest of the French naval construction societies. It gives employment to 7,500 workmen. The situation of its establishments at Havre, Marseilles, and Seyne, near Toulon, is exceptional, and permits it to manufacture the armament of ships *in situ*, and assures direct communication with the nations of the entire globe through the channel, the ocean, and the Mediterranean. Owing to such situation and to its thorough equipment, the society is able to deliver vessels of all types and tonnages, from the smallest steam launch up to the largest armor, clad.

During the war of 1870, as the state arsenals found it impossible to manufacture all the campaign *materiel* necessary, the government addressed itself to the society under consideration, whose works offered the valuable advantage of being situated at points of the French territory that the enemy could not reach.

The society hastened to adapt its tools to the manufacture of artillery *materiel*, and in a few months 300 guns and 1,200 carriages had left its shops. After the war was ended the needs of the state became only the more pressing, and the arsenals were much less able than in the past to supply them. The government was therefore obliged to ask for the co-operation of private industry again. The moment was particularly favorable to a more marked development and specialization of the means of productions of shops, in view of the manufacture of guns, carriages, and projectiles of the type prescribed by the government. And the moment was particularly favorable for permitting naval construction societies, like the Societe des Forges et Chantiers, to extricate themselves, from the false position in which they had been placed until then, and to so extend their works as to be able to deliver, all armed, such war vessels as they should have to build. This was at once seen by Mr. Behic, of the Societe des Forges et Chantiers.

But in this, as in other things, it did not suffice to lay down the principle; but it was farther necessary to grasp with accuracy, in their exact limits, the means best adapted to putting the principle in view in profitable execution; and to know how to select with certainty the colaborers best fitted for carrying out the measures.

Mr. Behic justly said to himself that to unite the production of the raw material and the manufacture of the same into finished products would impose the necessity of finding united at the same point a series of diverse economic conditions, all equally favorable, and that such a union was difficult to meet with. In such an opposition of interests, the establishment that works the crude material without manufacturing it does not hesitate to expend costly hand labor upon a material whose quality it has thoroughly assured itself of; and we may say that such opposition of interests constitutes for the buyer so much the better guarantee of the perfection of the product in proportion as it is the more marked. This principle of separation once admitted, the solution that naturally occurred to Mr. Behic for the manufacture of material of war was to annex the factory fitted with special tools to this effect to one of those owned by the society, in order that the two might aid each other when occasion required it.

FIG. 1.—CANET 11-INCH GUN, WITH CENTRAL PIVOT AND HYDRAULIC BRAKE CARRIAGE.

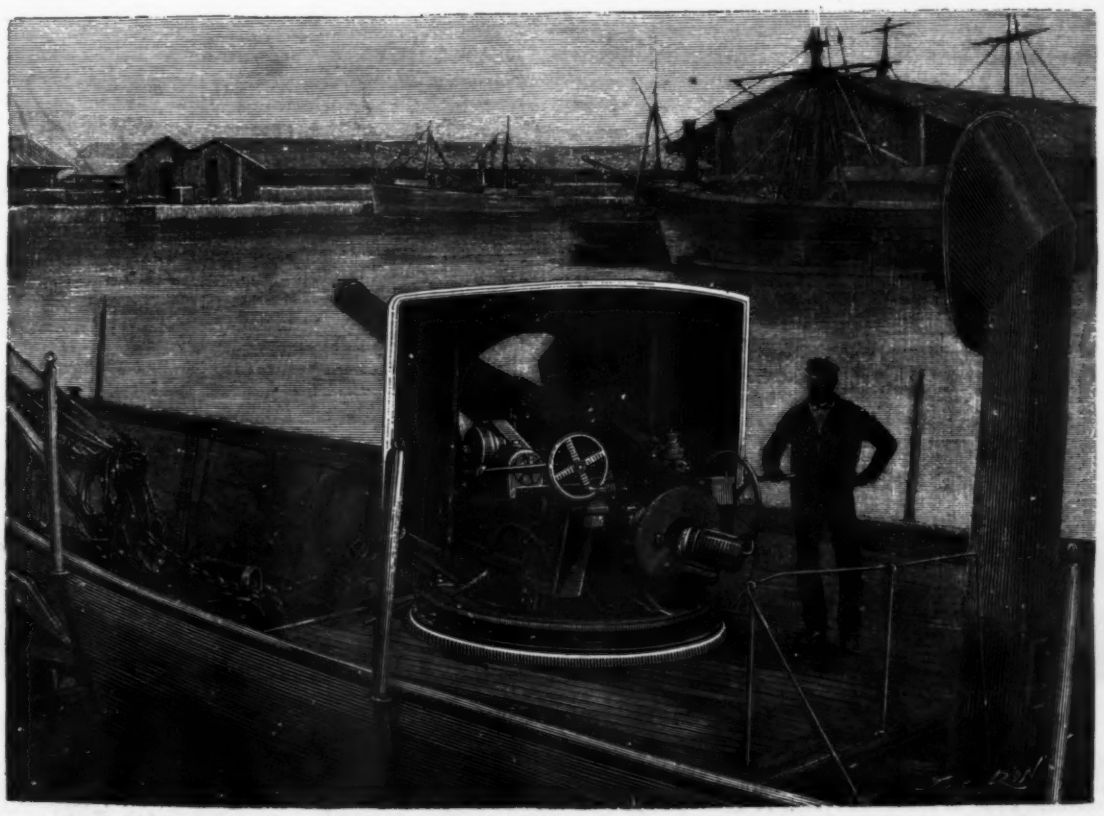


FIG. 2.—CANET 6-INCH GUN MOUNTED UPON A CENTRAL PIVOT MARINE CARRIAGE.

Mr. Behic selected Mr. Canet as his colaborer in the establishment of the works for the manufacture of artillery *materiel*. In offering his aid to Mr. Behic, this engineer contributed a series of improvements in the art of artillery which had been devised by him. Instead of confining himself to the study of a limited number of guns established under particular conditions and according to the needs of the moment, Mr. Canet had conceived of a series of guns responding as a whole to the exigences of land and sea service, and from among which any government, having need of artillery, could select the cannon answering a determined programme. All cases were provided for: For campaign and mountain services, 5 types of 75 mm. caliber; for rapid fire, a short and a long type, from 7½ cm. to 15 cm.; mortars of from 7½ cm. to 32 cm.; howitzers of from 12 cm. to 42 cm.; siege and short place guns of 10 cm. to 27 cm.; siege and long place guns of 10 cm. to 22 cm.; coast and naval guns of 9 cm. to 42 cm. To each of these latter correspond six different types, of 18, 24, 30, 36, 42, and 48 calibers.

For certain calibers there exist then (counting the mortars and howitzers) as many as 12 different types of guns. The projectiles in weight and shape differ according to the exigences of the service, and are thrown with initial velocities varying from 200 to 800 meters.

The breeches differ according to the needs of the service. There are six types. The same is the case with the carriages, each of which is adapted to the use that is to be made of the gun. In fact, the system is a very complete one.

Without speaking of a host of improvements due to Mr. Canet, we shall mention particularly those that he has introduced into the construction of guns in the way of closing the breeches. We may mention, too, the true perfection of the types of carriages with hydraulic brakes for large coast and marine guns. The arrangement of the parts of the brake permits of following step by step the variation in the power of recoil, of obtaining a very regular operation, and of therefore avoiding jerking of the carriage. In the Canet system a coast gun carriage, instead of having the cumbersome dimensions of those of former times, is nothing more than a turret whose diameter is no more than about a third of the length of the piece (Fig. 1). This carriage has been put to the test, and more than one hundred of this type have been ordered by the French government for coast protection.

We owe likewise to Mr. Canet the first center-loading turrets. These turrets, which carry a central tube movable with the revolving platform, permit of effecting the loading in all positions. The artilleryman can therefore continue to follow the object without having to trouble himself with bringing back the gun to the fixed position for loading.

Mr. Behic and Mr. Canet quickly understood each other. In face of the enormous needs of the state, it became easy to get a law passed authorizing the private manufacture of war material in France. Thereupon, being assured as to the future of the capital that he proposed to invest, Mr. Behic easily made the other members of the Council of Administration of the Societe des Forges et Chantiers share his convictions. The construction of special works was then decided upon, and to this effect all the sums necessary were put at Mr. Canet's disposal. Under his direction, eight years ago, the society unhesitatingly made the greatest sacrifices to unite in a model artillery establishment the most powerful means of action and the most improved tools. So it is able to manufacture guns of all calibers, from the mountain one of 100 kg. to the 100 ton marine and coast ones.

The works are situated at Havre, alongside of the old machinery works, which lend them the aid of their tools for the manufacture of gun carriages under the direction of Mr. Cazaran. The manufacture of turrets and hydraulic apparatus is carried on at the Seyne works. All the studies of guns and carriages are made at Paris under the eye of Mr. Canet. The direction of the Havre works is confided to Commander Roger, who has had great experience in the construction of artillery.

Finally, this establishment for the manufacture of material of war has been completed by the formation of a shooting range (Fig. 3), situated at the mouth of the Seine, at Hoc Point. Placed near the works, with which it is connected by a railway, this range permits of making, with all the precision desirable, trials of cannon of all calibers.

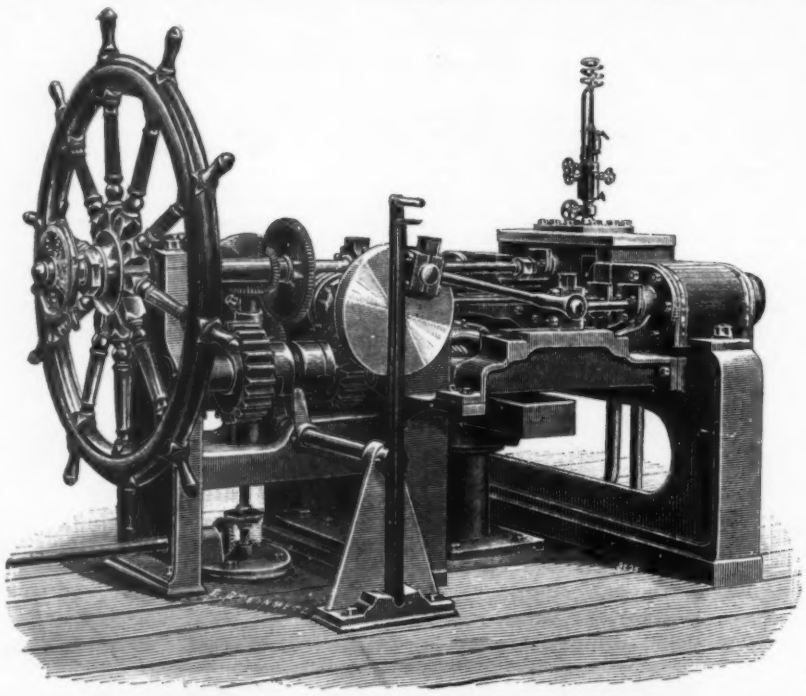
Upon the whole, it would be difficult to find another establishment having at its disposal an artillery service whose organization is so complete, and so this service has rapidly developed. Several states have discarded the Krupp system and the Armstrong guns to adopt the Canet artillery system, the recent experiments with which have shown its incontestable superiority.

So the Societe des Forges et Chantiers is in a position to construct every type of campaign, siege, coast, and marine gun, and gun carriage, either of the Canet system, which is its specialty, or of the French and foreign regulation models. It has, moreover, been able to make governments appreciate the advantage of confiding to one and the same establishment the construction of ships and their armament, in order that the vessels, guns, and carriages shall form a perfectly arranged system as a whole, this being something that can really be obtained only by the agreement of one and the same group of engineers working together and with the same views. And by this it has victoriously demonstrated that French industry is capable of competing with the extensive establishments of both Germany and England, which, hitherto, seem to have monopolized this business.—*Le Genie Civil* (*Abstract*).

NAPIER'S STEERING GEAR.

WE give an illustration of a combined steam and hand steering gear made by Messrs. Napier Brothers, of Glasgow. The advantages claimed for this gear are that, being placed aft, directly over the rudder head, there are no chains or quadrants to give any trouble, and the rattling noise of chains over saloons is avoided. There is a right and left hand screw keyed on the crankshaft and gearing into wormwheels on to the rudder screws; these are connected direct on to rudder crosshead by sliding blocks. The screws prevent all shocks produced by the rudder from coming on the engine, as well as on the steering wheel when steering by hand, and being always connected to the rudder—whether the steam or the hand, or even when neither is in gear—prevent the rudder becoming loose and charging, acting, in fact, the part of a rudder brake. Only one clutch, the clutch between the worm and spur wheels, has to be moved to connect either the steam or the hand gear, and this can be done at any position of the rudder. The steam gear is perfectly noiseless, as there is only worm and screw gear, the spur gear being only used when steering by hand. The valves are all simple and easily got at when wanted, and can be worked either from the stern or from the bridge. For the latter mode of working a small shaft is led from the valve at the steering gear to the bridge wheel. In the hand gear the power increases as the rudder goes over.

This steering gear, which is now being largely adopted by many of the largest shipping companies, has been fitted on the State Line, the Allan Line, Union Line, and a number of other steamers. The illustration shows the gear as fitted on the s.s. State of Nevada, 2,500 tons, and has been successfully working on that vessel for the last year.—*Engineering*.



COMBINED HAND AND STEAM STEERING GEAR.

IMPROVED COLLAPSIBLE LIFEBOAT.

THE engravings illustrate the collapsible lifeboat invented by Mr. Charles Henderson, Glasgow. One of the boats, says *Engineering*, was exhibited on a staging at the side of the River Kelvin, within the grounds of the Glasgow exhibition, and, by means of davits, demonstrations were given at stated hours of

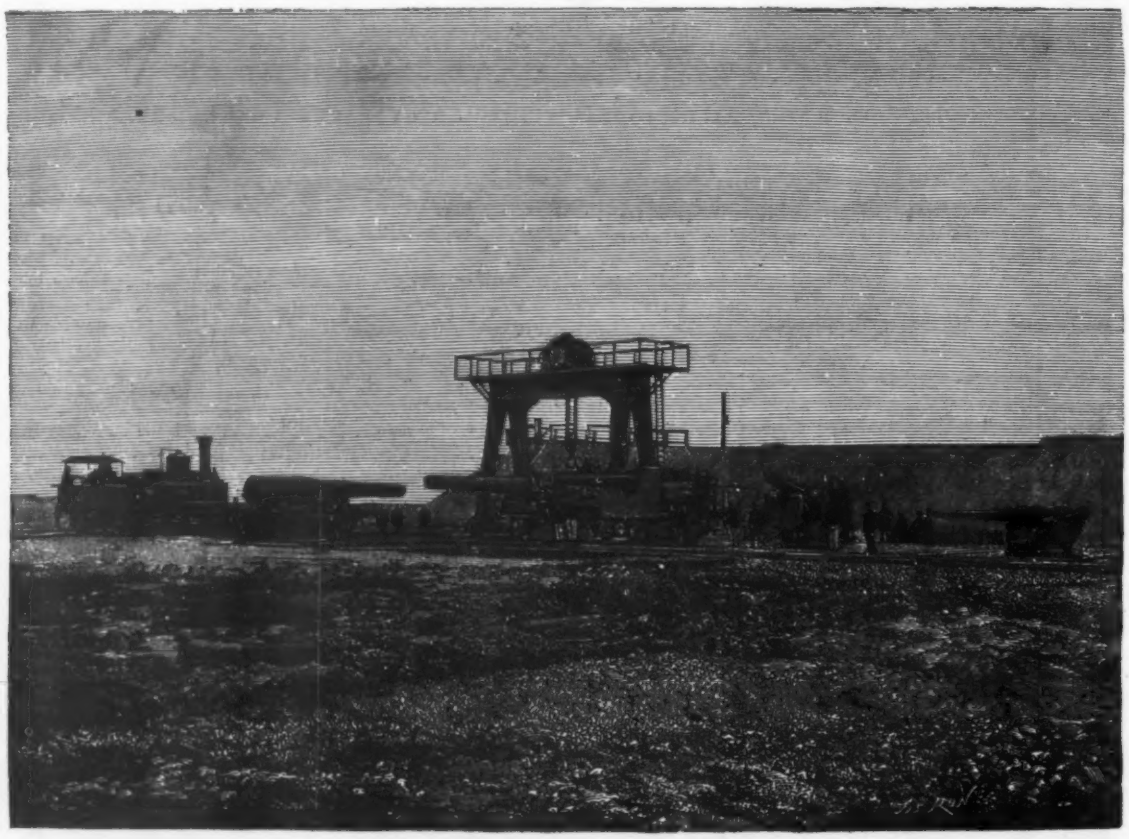


FIG. 3.—FIELD FOR TESTING ARTILLERY.

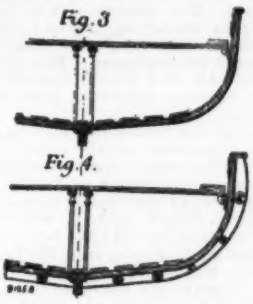
launching, embarking, and collapsing the boat. The capabilities of the craft were thus clearly shown. Mr. Thomas Gray, C.B., secretary, Captain Price, and other officials of the Board of Trade, and surveyors of Lloyd's, attended together and saw the boat launched in one minute. Prior to this inspection the boat had

been formed and collapsed over 500 times, and had been launched over 50 times, on each occasion with passengers on board varying from 20 to 64 in number.

The chief feature of novelty is in the method of collapsing. Fig. 1 is a longitudinal section of a boat 26 ft. long, 8 ft. beam, and 3 ft. 3 in. deep, having buoyancy for 60 passengers, while Fig. 2 is a plan of the boat, erect and collapsed. The keel is formed of wood and metal combined, as illustrated in Fig. 10. The frames are made of wood and angle steel galvanized, secured to the gunwale by metal joints (Figs. 13 and 14). They are fastened to the keel, as is shown in Fig. 10, by means of the hook ends of vertical stays supporting the seats of the boat from the keel. The fastening permits of the fore and aft motion necessary for the collapsing of the boat.

The frames are united together at the bottom by connecting rods (Fig. 1). This figure also shows flexible V shaped frames fore and aft, the extremities being attached to the gunwale and the apex to the end of the keel. These V frames are formed of wire rope with wooden thimbles to prevent chafing on the canvas. The ordinary frames are divided into two equal groups and arranged to slide along the keel in an aft or forward direction (Fig. 5). The bottom of the forward and aft frames are connected by wire rope, the former to the sternpost and the latter to the stem (Fig. 5). On the stem and sternpost being raised to the vertical position in the act of forming the boat, these wire ropes draw the bottom of the frames along the keel until an upright position is attained, when the frames are firmly locked in position by the automatic device shown in Fig. 12. Connection is formed between the bottom of the frames and the center of each seat by means of the vertical stays already referred to.

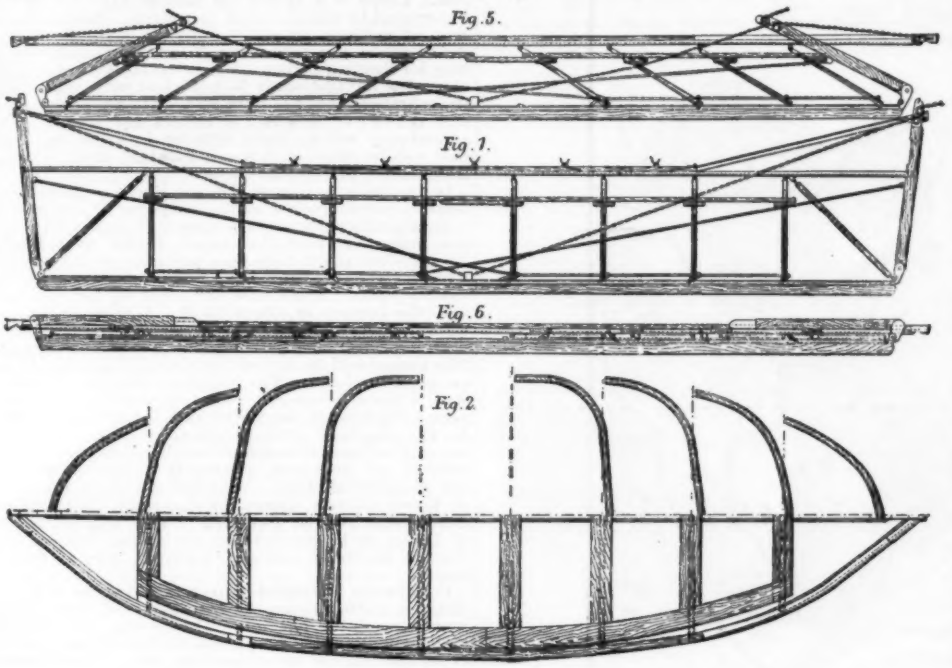
The gunwale is of wood and angle steel galvanized, secured to the head of each frame by a joint (Fig. 13). To obtain the necessary sheer a portion of the gunwale at either end of the boat is made double, the upper part being so hinged as to permit of the extremity at bow and stern being raised 18 in. higher than the horizontal line. The stem and sternpost are formed of wood, having at the lower end a strong gun metal hinge, which allows of their being folded down to the horizontal position when the boat is collapsing. The upper end of each is furnished with the necessary lowering and erecting gear, consisting of two pulleys and

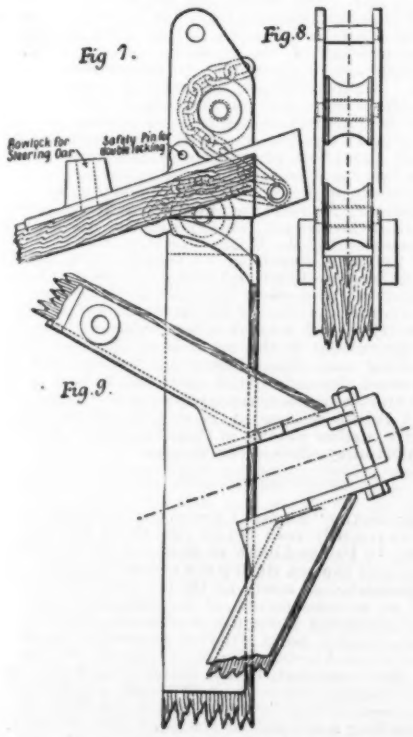


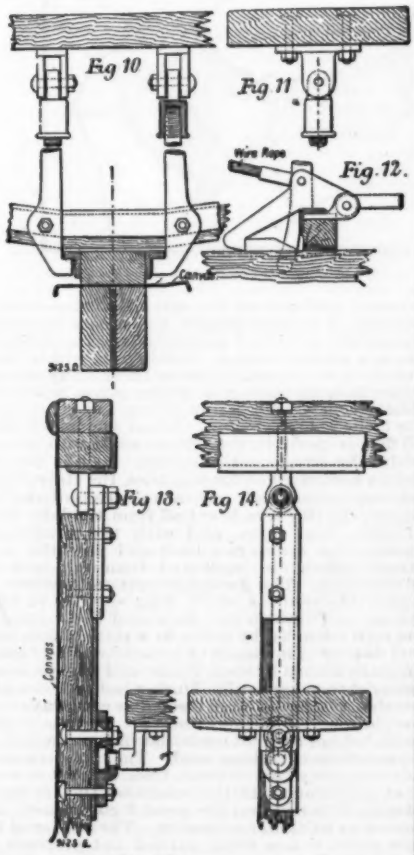
inclined plane, with locking catch, Figs. 7 and 8. The gearing includes two chains, secured by one bolt which passes through the apex of the gunwale (Fig. 9). The lower chain is led over a pulley from the head of the sternpost to the keel amidships, through an eyebolt there, and from thence is continued to the top of stem, all as indicated in Fig. 1. This, when the boat is in position, forms a supporting stay for the center of the boat on the principle of a suspension bridge. When the stem and sternpost are being raised in the act of forming, the chain, being over the pulley, serves the purpose of raising that portion of the gunwale fore and aft forming the sheer of the boat. The upper chain passes over the upper pulley in the stem and sternpost as shown in Fig. 7, this being for the purpose of erecting the boat.

To collapse the boat the apex of the gunwale at each end is slightly raised so as to free the locking catch and allow the stem and sternpost to be folded down. The locking catch securing the forward and aft groups of frames in a vertical position being relieved, they are tripped as in Fig. 5, and soon the gunwale, etc., attains the horizontal position in Fig. 6, the frames assuming the position shown in plan, Fig. 2. To raise the boat, the upper chain on stem and sternpost is drawn; and it is long enough to allow five men to engage in the work. By pulling these the boat can be formed and automatically locked in position in five seconds. The bottom boards, it should be stated, move along with the frames in a fore and aft direction.

The covering of the boat, in its simplest form, is two plies of specially prepared rot-proof and water-proof canvas. It is securely fastened to the gunwale, and passes between the keel and the keelson (Fig. 10). It will thus be seen that the canvas forms a continuous bag, and is thus specially suited to resist any local strain. When it is desired to employ a double skin, it is secured to the gunwale and keel as in Fig. 4. Between the two skins are arranged fore and aft longitudinal fenders about 3 in. in diameter. These are secured to the inner skin, and on plan approximately represent the water lines of the boat.







IMPROVED COLLAPSIBLE LIFEBOAT.

DRAINAGE OF THE MEXICO VALLEY.

AN important contract for a tunnel, having for its object the drainage of the valley and city of Mexico, has lately been let to Messrs. Read & Campbell, of London and Mexico city; and as the conditions and objects for which the work is being done are somewhat remarkable, we propose to give a short account of the works, and to render this the more intelligible it will be well, in the first instance, to describe the position and surroundings of the city. The valley of Mexico is comprehended between 19 deg. and 20 deg. N. latitude and between 98 deg. 41 min. and 99 deg. 9 min. W. longitude. The city of Mexico, in the center of the valley, is in latitude 19 deg. 26 min. 5 sec. N., and in longitude 99 deg. 6 min. 45 sec. W. The valley is bounded on the north and west by the mountain chain of Paelmea and the smaller ranges that converge upon the Sierra of Tezonthalpan. To the southward the Cordilleras of Ajurco close in the valley, while to the eastward the Sierra Nevada complete the inclosure, which has no natural outlet. The highest mountains, which include the celebrated volcanoes of Popocatapetl and Ixtaccihuatl, some 17,000 ft. above sea level, are on the eastern side, while the Peak of Ajurco, 13,000 ft., lies in the southern chain. The lowest point of the enclosure is directly north of the city of Mexico. At this point the hills are only 328 ft. higher than the lowest part of the valley, and it is here that the drainage tunnel will be made. The bottom of the valley is a nearly level plain of an oval shape, with its longest diameter from N. to S. about 47 miles, and its shortest from E. to W. about 32 miles. The plain is interrupted by a few eminences, of which the Guadalupe hills, stretching into the center of the valley from the west side, are the most notable. The average altitude of the valley is 7,412 ft. above sea level, and its area 1,657 square miles. The total area of the hydrographic surface of the valley, including the bottom, and the mountain sides that drain toward the interior, is about 2,711 square miles.

In the valley there are six lakes of considerable size, forming a crescent around the city of Mexico. Of these lakes, Chalco and Xochimilco are to the southeast of the city, Lake Texcoco to the eastward, San Cristobal and Xaltocan to the northeast, and Lake Zumpango to the north. Of these, Texcoco is the largest and among the shallowest, while Chalco and Xochimilco are the two deepest. There are four drainage planes in the valley; the highest is Lake Zumpango, the next that of Xaltocan and San Cristobal, the third that of Chalco and Xochimilco, and the last and lowest is that of Texcoco, upon whose banks stands the city of Mexico. The latter would naturally receive the waters of all the rest but for certain restraints, natural and artificial, which prevent this and render the city safe. In former years Lake Zumpango was the point where danger of overflow was greatest, as it then received the waters of the river Cuautitlan, which drains a large extent of country. This river is now led through the Vertideros canal into the Tajo, or cut of Nochistongo. Thus this source of peril is removed. The waters of Zumpango, Chalco, and Xochimilco are derived from springs and clear brooks, and are fresh and drinkable. On the contrary, the waters of Lakes San Cristobal and Xaltocan, and still more Lake Texcoco, are salt and bitter to such an extent as to be fatal to vegetation.

The rocks of which the mountain walls consist are igneous, metamorphic, and sedimentary. In the Sierra Nevada the rocks are principally dolomites and lavas. Metamorphic rocks are found in the form of limestone on the northern side of the valley, and sedimentary formations in the level ground of the center. On the floor of the valley there is a succession of beds of clay, marl, sand, and gravel. When the Aztecs in their march south arrived at the site of the city, the vast lake that once covered the whole valley had diminished in size, and had formed two lakes, a northern and a southern one. At the western part of the southern lake a ridge of unaltered rock emerged through the sedimentary rocks and its pinnacles came near the surface of the lake, and around these a marshy island formed which became the site of the city of Mexico. One of these pinnacles is said to be the site of the plaza of Santo Domingo; upon another pinnacle stands the present cathedral. The ridge of rock referred to extends in a southwest direction through the center of the city, and has been the principal cause of the formation of this land on which the city stands. At the time of the Spanish conquest there was a shallow arm of the lake on the north and south of the city, but at the present time the western shore of Lake Texcoco is at a distance of more than two miles from the nearest part of the city.

The rainfall in this district is about 20 in. annually; of this about one-third drains through the Cuautitlan river and the Nochistongo cut. Nearly half is used in irrigation, and the lakes finally receive about one-fifth

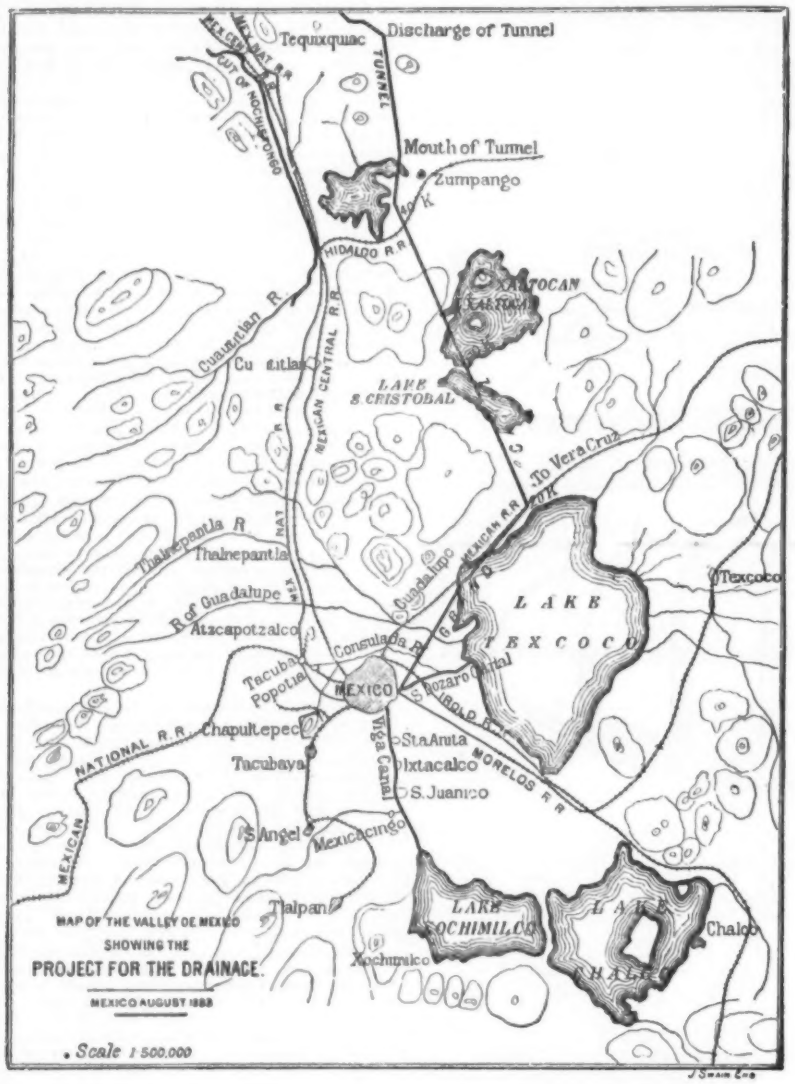
of the whole rainfall, or 787 million cubic meters in the course of an average year. The average daily inflow to the lakes is about 2¼ million cubic meters. The area of the lakes being very large, the evaporation is generally sufficient to dispose of the daily inflow. The bulk of the yearly rainfall takes place between June and October; at this time the evaporation is quite unable to remove the extra large volume of water then received by the lakes, and periodical inundations occur. During the rainy season the water is only kept from flooding the city by means of dikes. The city itself is then a closed area nearly surrounded by water, at a higher level than the ground inside the city defenses.

When the increasing area of dry land formed by natural, and perhaps artificial, means had encouraged the lake dwellers to cultivate and build houses, the pernicious effects of these annual inundations induced rude efforts, to restrain the waters; the first record of these efforts about one hundred years before the Spanish conquest, relates how the King of Texcoco, by arrangement with the Emperor of Mexico, sent 20,000 Indians to build a dike eight miles long across Lake Texcoco to prevent the waters of Cautitlan river from reaching the city. In the year 1604 a tunnel project was first considered, and in 1607 the Spanish engineer Enrico Martinez submitted to the viceroy a plan to drain the whole valley by a tunnel through the northern side. The work, however, was not carried out, but Lake Zumpango was drained and the river Cuautitlan regulated. In pursuance of this project Martinez cut a tunnel through the mountain wall at the spot where is now the Nochistongo cut; this tunnel was not lined, and gave constant trouble from falling in. It was afterward partially lined, when in 1629 there occurred the great inundations of Mexico, and the whole city was navigable by means of canoes; these floods lasted till 1634, when an earthquake released the waters.

A few years after this it was decided to convert the tunnel of Martinez into an open cut; this colossal work took 150 years, and the completed work appears more like a natural ravine than the result of man's labors. It is thirteen miles long and about 120 yards wide, and in some places is 200 ft. deep. After the completion of this great work nothing was done for many years, except as the fear of inundation compelled the ephemeral governments of the revolutionary period to cleanse the canals and repair the dikes. In 1856 a commission was appointed by the government to select from a number of schemes which had been proposed by various engineers for the drainage of the valley. The plan selected was that of Don Francesco Garay. Garay's plan provided for a tunnel to be driven through the northern side of the valley. He also provided a system of irrigating ditches and navigable canals to be supplied with water from Lake Zumpango. He proposed to drain Lake Texcoco entirely, and to reduce the other lakes to such dimensions as would remove all danger of their overflow.

The tunnel was to commence on the northern shore of Lake Zumpango, and terminate in a ravine called Ametlac, and it was about 75 kilometers long. It would have been supposed that nothing now remained but to carry out the plans as adopted; such was not the case. There were more revolutions in the government, and Garay's plans were lost sight of in the multitude of plans which were presented by different engineers, as they in turn were placed at the head of affairs by political changes. Those plans varied greatly, and each engineer adopted a different basis for his calculations. The plan which found favor provided for the prevention of the rising of the lakes beyond a certain level, the idea of rendering dry any, or all, of them being abandoned. The assertion as to the danger to public health from the laying dry of Lake Texcoco is supported by the medical faculty of Mexico, but is not universally shared by engineers. The plan of Garay has been abandoned, and the dimensions adopted for the work are entirely different from those recommended by him.

The direction of the tunnel has also been changed. Leaving Lake Zumpango at the point he suggested, the tunnel diverges some 10 deg. to the east of Garay's line and emerges in the ravine of Acathan, instead of Ametlac. The effect of this change is to make the tunnel some 2 kilom. longer than is necessary, or 9·52 kilom. Garay's tunnel would have been self-cleansing, whereas the canal leading away from the present tunnel, from its position, will require constant dredging. Up to the present time about 1,200 m. of the northern part of the tunnel have been finished, and thus, after some twenty-three years—for the works were commenced in 1866—the tunnel is further from completion than if the Garay route had been adhered to from the first. The



It was the intention of the late Emperor Maximilian—the ill-fated brother of the Emperor of Austria—to complete this work, and the country was surveyed with this intention, and the tunnel works were begun. Twenty-four shafts have been partially sunk, and some 1,000 meters of tunnel have been constructed during twenty years. The shafts are about 400 meters apart, and the deepest is about 300 ft. A large volume of water is met with, and to deal with this efficiently a bottom or drainage heading will first be run through. The tunnel will be driven both ways from each of the twenty-four shafts. The plant required is very extensive; 8 horse power and 10 horse power semi-fixed compound engines are being shipped for each shaft head for pumping and winding and ventilation. The tunnel will be lined throughout with brick made in the district, and the invert, as already mentioned, will consist of artificial stone. Ventilation will be by means of Roots blowers, driven by the same compound engines employed in pumping. The engines are by McLaren, of Leeds, and are on Halpin's system, consuming 2¼ lb. of coal per indicated horse power per hour.

Coal has to be imported from the United States—a distance of 2,000 miles—its cost delivered at the workings being £2 10s. per ton. The pumps will raise 150 gallons per minute; they are of the bucket and plunger type, with hollow wrought iron rods. About twenty million bricks will be used, and about thirty thousand 400 lb. barrels of Portland cement. Some ten thousand tons of lime, obtained near the works and burnt in special kilns constructed for the work, will be required. Sand of excellent quality can be obtained at a distance of about six miles. Alwin's and Clayton and Howlett's brickmaking machines will be used, of a total capacity of 60,000 per day. The Wells light will be used in the shafts. The enlightenment of the tunnel will be done by the contractors, considerable skill and care being required on account of the smallness of the shafts, which having been begun, have to be continued the same size. English foremen, bricklayers, miners, and mechanics have been sent out specially for the work, but native Indians will be employed for general labor, the approximate number employed being about 2,500. Mr. Albert Campbell, whose energy and hard work enabled a London syndicate to make a contract with the corporation of the city of Mexico, and to raise the capital necessary for carrying out the works, is at present resident in Mexico and supervising the works, being ably assisted by Mr. Mears, who has had a considerable previous experience of tunnel work. The contractors, Messrs. Read and Campbell, are likewise constructing at the present time the Mexican Southern Railway, and a portion of the interoceanic railroad, and are carrying out several other important works for the improvement of the republic of Mexico. The accompanying map shows clearly the features of the country passed through by the canal and tunnel, and also gives an idea of the necessity for the work for the safety and future welfare of the city of Mexico. We hope to give further details of these important works as the opportunity offers.—*The Engineer.*

A PAPER on the "Surface Currents of the North Atlantic" was recently read before the Paris Academy of Sciences, by Prince Albert of Monaco. Of the 1,675 floats cast into the sea during the recent explorations of the Hirondelle, as many as 146 have already been recovered at various points of the seaboard, apparently demonstrating a circular movement of the surface waters round a point situated somewhere to the southwest of the Azores. The outer edge of this current sets east-northeast, to the neighborhood of the English Channel, where it is deflected southward along the coasts of Europe and Africa to the Canaries, thence trending southeast to the equatorial current, thus completing the circuit by merging in the Gulf Stream.

HERMANN GRUSON.

LAST month one of the most eminent German engineers, Privy Councilor Hermann Gruson, of Magdeburg, Buckau, celebrated the fiftieth anniversary of his career as an engineer. From small beginnings this man, whose name is also not unknown in this country, created an establishment which employs to-day over 3,000 workmen, and which has a world-wide reputation, more especially for the manufacture of war material. Gruson's chilled cast iron armor is known all over the world, and finds its application in most of the recently erected fortifications in Belgium, Holland, Germany, Austria, Roumania, Italy, Denmark, and is certain to be applied also one day in this country.

Born in 1821, the son of a Prussian engineer major, who constructed one of the earliest railway lines in Germany, Gruson studied at the University of Berlin, and at the same time tried to gain practical experience as an engineer in one of the large engine building works at Berlin. In 1855 Gruson commenced business on his own account on a very small scale on the banks of the Elbe, as a boatbuilder, with small engine works attached. This led him by an accident to develop also the process of making chilled cast iron, by giving to cast iron a particularly hard surface through the employment of iron moulds, a process which had been known long ago, and which was much used at the time in England.

At first he made chiefly crossings for railway switches, bnt presently he commenced to develop his works for making also chilled shot for the Prussian government. For many years this branch of the works brought him large orders until the introduction of steel shells, which have now superseded the old chilled shot. His experiments in this direction had, however, led Gruson also largely to the introduction of chilled cast iron as a protection for turrets and batteries for coast fortifications, and Gruson's works reached a development which would not have been thought of in their earlier days. In 1886 the well known trials at Spezzia led to an order for two large armor turrets for Italy, armed with Krupp's 40 cm. guns, and on all parts of the coasts of northern Europe Gruson's turrets are now to be found as coast defenses. During the past three years the system of shielded mountings, known as the Schumann system, has also been added to the wide range of Gruson's specialties, and his quick fire guns are coming prominently to the front. The creation of an establishment covering now many acres of ground, turning out many thousands of tons of finished iron in war material, machinery, etc., is due chiefly to the industry, energy, and perseverance of Gruson, whose name will be handed down as one of the most prominent Continental engineers.—*The Engineer*.

MINERAL WAX.

History.—Mineral or earth wax, ceresin, ozokerite or ozocerite (from ὀζειν, to smell, and κηρος, wax) is a solid mineral belonging to the hydrocarbon family, and is practically a native paraffin. Toward the close of the last decade its occurrence was discovered in Utah, and at once every miner had a claim of it for sale. It was given a value of from five cents to a dollar a pound, and asphalt, dried petroleum, or, indeed, any mineral containing organic matter, was at once regarded as mineral wax. Specimens were sent to New York City, to Boston, and elsewhere, and its utility was conceded, but the absence of a refinery in this country soon led to the abandonment of any attempt to place it on the market. The most valuable property passed into the hands of a New York house, which has developed it, until at present there is a continually increasing demand for its product.

Geographical Distribution.—In Europe small quantities of it have been discovered in England, at Binney quarry, Linlithgowshire, at the Urpeth colliery, Newcastle-on-Tyne, and in Wales. It is also found in Moldavia, and in the neighborhood of Agram, in Croatia, but the most important deposits are in Galicia, at the northern foot of the Carpathian mountains. The exact localities are Boryslaw, Truskawiec, Dwiniacz, and Starunia; the first named being the most valuable. In this country its occurrence is reported about fifty miles northeast of Los Angeles, California; in Texas and in Utah. The only working deposits are those of Utah, which are situated near Pleasant Valley Junction and Soldiers' Summit, 114 miles east of Salt Lake City, on the Denver and Rio Grande Railway.

Mode of Occurrence.—In Galicia mineral wax is found in miocene clay shales and clay marls with the intercalated sandstone, and it frequently accompanies rock salt and gypsum. At Boryslaw it is found after a depth of from 20 to 70 feet, and some shafts have been sunk 700 feet, where the accompanying rock is strongly impregnated with oil. At Truskawiec there are surface veins of the wax, and the shafts have not been sunk so deep. A black oil, which is used for axle grease and all kinds of lubricants, filtrates through the crevices in the earth, and by pressure, heat, and the accompanying chemical decomposition forms the wax. The Utah deposits, which are larger than any yet discovered, cover an area of eight miles long by one and a half wide, through which the White River passes. There are numerous bodies of the wax exposed to view on the surface, and, while they are narrow at their outcrops, they increase in thickness as they go down, and the quantity that can be derived from them is only limited by the extent of ground opened. At present writing open cuts of 100 feet long and shafts 50 feet deep have been made in various places, and hoisting machinery put in. Prof. John S. Newberry regards it as an evolved product, the distillation of beds of cretaceous lignite and the residue of a petroleum unusually rich in paraffin.

Physical Properties.—Pure specimens resemble resinous wax in consistency and translucency, sometimes with a foliated structure. Its color is brown or brownish yellow by transmitted light, and leek green by reflected light. The poorer qualities, which are colored black, and are either too soft from abundance of petroleum, or too hard (asphalt-like in character), are used abroad for the production of paraffin. The American mineral is dark brown on the surface, but grows lighter in color as the deposit is worked. Energetic chemical reagents, such as sulphuric and nitric acids and alkalies, have no action on it. It is odorless and tasteless.

Chemical Nature.—The specific gravity of mineral wax is 0·94 to 0·97. According to Dana, it ranges from 0·85 to 0·90.

Its melting point is variously given as follows:

Moldavian.....	84° C.	Malaguti.
Urpeth.	60°	Johnson.
Galician.....	60°	Hofstadter.
Utah	61·5°	S. B. Newberry.
Moldavian.....	62°	Schrotter.
Slanik	62°	Glocker.
Galician.....	63°	Wagner.

The boiling point is likewise differently given by the authorities:

Urpeth	121·6°	Johnson.
Moldavian	210°	Schrotter.
Moldavian.....	300°	Malaguti.
Utah.....	300°–380°	S. B. Newberry.

Concerning the last determination Prof. S. B. Newberry says: "1·5 grammes of the substance were treated with about 300 c. c. of cold ether and allowed to stand for twenty-four hours. The solution was decanted through a filter, evaporated, and the resulting mineral tested to obtain the melting point. This treatment gave a fraction equal to 25·4 of the original substance and having a melting point of 49° C. The residue was again tested with 200 c. c. of cold ether for about the same time, and gave a further product equal to 9·1 per cent. of the original mass, fusing at 61°. On boiling the undissolved portion in about 500 c. c. of ether, the whole mass went into solution, and upon evaporating it was found to have a fusing point of 67°."* It distills without decomposition, is not altered by strong acids and very little by hot alcohol, but is soluble in ether, turpentine, or naphtha. The Moldavian variety dissolves but slightly in ether, whereas that found in Urpeth dissolves in that medium to the amount of four-fifths, and separates on evaporation in brown flecks, which melt at 38·9° to a yellowish brown liquid. The solubility of the variety found in Utah has been sufficiently referred to in the remarks on its fusing point. The composition of mineral wax has been found to be:

HERMANN GRUSON.

	Moldavian. Malagnti.	Schrotter.	Urpeth. Johnson.	Utah. S. W. Newberry.
Carbon....	85·75	86·20	86·80	86·15
Hydrogen.	15·15	13·77	14·06	13·75
	100·90	99·97	100·80	99·90

It is supposed to be composed of several members of the paraffin series which are represented by the general formula $C_n H_{2n} + _2$, and, perhaps, contains certain of the olefines. A very elaborate description of the chemical composition of a specimen of mineral wax found in Kinghornness, Scotland, was given in a paper read by W. Ivison Macadam, at the Sheffield meeting of the British Association in 1879.†

Refining.—In this country the crude wax does not go through any process of refining other than washing. It is thrown into tanks filled with water, which causes the accompanying clay to separate and sink while the wax floats. The increasing demand for it will doubtless soon result in the erection of a refinery in Utah. In Galicia, the wax is first melted under water, by means of which the greater portion of it is removed; but the residue still contains as much as 12 per cent. of wax. These residues were collected in enormous quantities, and were for a long time considered a nuisance. In 1883 J. Merz began working them with an extraction apparatus of his own; but subsequently a French company succeeded in buying them up and has since been engaged in working them. Originally the crude hydrocarbon was simply melted and then drawn off, the residue being boiled with water, to the surface of which any remaining wax rose, and then allowed to stand for some time in order to allow any suspended impurities to settle out. The melting wax which was drawn off was poured into moulds holding from 100 to 120 pounds. These cakes were then shipped to the various factories, where the wax was purified and converted into illuminating oils and paraffin.

In order to obtain from the crude material a pure white ceresin of a high fusing point, Dr. Oscar von Gruber proceeds in the following manner: 100 parts of the wax are treated with five parts fuming sulphuric acid at 80 degrees C. The dark resin which precipitates within an hour and a half is removed; the dark greenish fluid is then mixed with 10 parts of a solution of silicate of soda, heated to 80 degrees C., and maintained at that temperature for one hour with constant stirring. If 200 parts water are next added, the emulsion decomposes with the separation of the silica and pigment. The yellowish gray ceresin floating on the surface is at once drawn off and mixed with equal parts of a "nitrogenous carbon," specially prepared by the inventor, with which it is left for two hours at 80 degrees C. The mass is next digested with naphtha ether having a boiling point of 40 to 60 degrees, in a specially constructed apparatus, and the naphtha distilled off, yielding 70 per cent. of a fine white ceresin. The carbon is treated in retorts in the usual manner, and the residues from the treatment with sulphuric acid are worked into paraffin and oil. Another method by which the crude wax is refined and bleached in a single operation is that devised by Hersch Goldhamer, who heats 100 kilogrammes in an open wrought iron kettle over a hot fire at 180 degrees C., until the admixed water and light oil are evaporated. The mass is then cooled to 100 degrees C., and mixed while stirring with 10 kilogrammes of sulphuric acid of 66 degrees Baume. It is then heated again to 180 degrees, until a sample of the mass passed through filter paper yields transparent white drops. Next it is cooled to 100 degrees C. and 20 kilogrammes dry and finely ground sediment of potassium ferrocyanide are added, with which it is again heated to 180 degrees C. until effervescence ceases. The mass is poured into sheet tin coolers, pressed in a stearin hot press, and the press residue passed through an unsized filter heated by steam. Subsequently superheated steam was used to purify the paraffin by blowing out the contaminating oils. The chief improvements in recent years have been devoted to a profitable utilization of the residues. Two methods are in common practice. The first and simpler consists in heating the wax with fuming or common oil of vitriol to 200 degrees C. until the greater part of the material is removed, either by decomposition or by evaporation, and then heating it at a suitable temperature with neutralizing and decolorizing agents, such as alumina, silicates, bone ash, the refuse of prussiate factories, and similar substances. By the second method the resinous and discoloring constituents of the wax are also removed with acid, but at a relatively low temperature, thus avoiding so thorough a decomposition. The refineries are located in London, Glasgow, Vienna, Frankfort-on-Main, Buda-Pesth, and a few other places in Russian Poland, France, Germany, and Belgium.

Uses.—In Europe about one-third of the mineral wax that comes to the market is worked into paraffin, and the remainder into ceresin. In Galicia the demand for paraffin made from it is said to be on the increase, as a large part of it is consumed there in making the candles used in their religious rites by the Jewish and Catholic inhabitants. The product for this purpose does not require so careful purification as that used for other purposes. The material from the Utah deposits (that is, the unrefined mineral), owing to its high melting point, its plasticity without being soft, and its hardness without being brittle, has led to its use in insulating electrical wires for underground and line uses.

The experiments thus far made show that for this purpose, all things being considered, mineral wax compares favorably with other substances. It is now used by eight of the electric companies. It finds extensive use in electrotyping and in stereotyping, also in etching on steel plates. As a body and as imparting luster it is used in many kinds of shoe blacking, and is sought for in the making of sealing wax. Mixed with oil, it forms a lubricant for rapid running machinery. Among the many uses for which it is recommended is as a base for a cheap composite paving material and for indurating piles and posts to prevent decay. Mineral wax is applicable for all kinds of waterproofing, and paper treated with it has been used in preference to oil paper. There has been a large demand for it in wrapping soaps, metals, books, and all articles which require protection from moisture.

When refined it is used as an adulterant of beeswax, and as it is one-third the price of the latter, and when refined can be used as an adulterant, taking its place, and is applicable to much the same uses as the beeswax itself. It is used to protect boxes, tubs, barrels, and kegs, and such when lined with it become tight, as the wax permeates the pores of the wood instead of giving it a mere surface coating, and it imparts no odor to the contents, even if they are the most delicate mineral waters. A recent interesting application is in coating the paper cylinders on which the graphophone stylus traces its record. One of its most valuable uses is in the manufacture of candles, which, owing to their high melting point, do not soften or bend at an ordinary temperature. Such candles are claimed to exceed all others in illuminating power. Thus 754 grains of mineral wax give as much light as 791–798 of paraffin, 1,000 of the best spermaceti, and 1,150 of wax candles. For this purpose its value is very great, and as there are 20,000 pounds of candles now used daily in the Rocky Mountain region, costing from 11 to 15 cents a pound, it is believed that when a refinery is built in the Utah district, much of this trade will be lost to Eastern candle makers. Its other uses are as a vehicle in the making of liniments, salves, and plasters, in making wax matches, coating life preservers, as varnishes, shoemaker's wax, wax figures, doll heads, and similar articles.

Statistics.—The value at the mine of the American mineral wax when in good, clean condition is 4@5 cents a pound, and delivered in New York City 6@10 cents a pound, according to quality. The output at present is 10 tons a month, but it is expected that the yield for the present year will amount to 1,500 tons. The Galician deposits have since 1861 produced wax valued at about $40,000,000, and the present output is about 300 tons a week. At the seaboard the crude mineral wax is worth about $130 a ton, and the grade known as "Hoch Prima" brings £30 a ton delivered in London, where it is nearly all absorbed by a large firm of candle makers. The annual imports of crude mineral wax into this country amount to about 500 tons, and the refined article, ceresin, to about 400,000 pounds.—*Engineering and Mining Journal.*

* *Engineering and Mining Journal*, March 22, 1879.

† *Chemical News*, vol. 40, p. 148.

WHITE WOOLENS.

As is well known, it is impossible, even with the most energetic bleaching agents, to remove from wool a slightly yellow tinge which is readily seen if bleached wool is compared with bleached cotton or silk. When attempts are made to hide this shade by means of a complementary blue, as is done on cottons, curtains, papers, etc., bad results are obtained.

Many attempts have been made to give the wool a brilliant white by covering it with white substances, such as carbonate of magnesia for example, and this was used for some time for this purpose. But its use has been abandoned on account of the dust which comes from the wool when the goods are in store. It has also been proposed to cover the wool with cotton by dissolving the cotton in ammoniacal copper solution, impregnating the wool with solution, and then fixing the cotton on the wool by means of acid. An ether bath has been finally applied to render the cellulose opaque.

Hallab reaches the desired result by the use of hydrosulphite of soda and indigo. The effect is a double one; the hydrosulphite acts as an energetic bleaching agent, and on the other hand it renders the indigo which is deposited mechanically upon the fiber soluble and causes it to penetrate the fiber. By subsequent oxidation in the air, the indigo comes out with a complementary blue shade which neutralizes the yellow of the wool. It is doubtful, however, if an absolutely perfect neutralization of the yellow can be reached with a blue pigment in this way.

As we have said above, the numerous experiments with different coloring matters, such as ultramarine, sulphindigotic acid, aniline blues, etc., have failed to give satisfaction.

The following receipt for the use of hydrosulphite is taken from the *Deutsche Farb.-Zeit.* The hydrosulphite of soda should be made just before it is to be used. Digest seven parts of zinc powder or twenty to thirty parts of feathered zinc or sheet zinc with a concentrated solution of bisulphite of soda representing 100 parts of the dry salt. This must be done in a closed vessel, and the mixture must be stirred from time to time for an hour. Decant the clear liquor which contains the hydrosulphites of soda and zinc.

The woolen must be carefully purified, washed, and scoured, and then worked in a bath of cold water containing indigo in suspension in a very finely divided state. The best indigo to use is that which furnishes reddish-blue shades in an ordinary vat. The wool should come from the bath evenly covered upon the surface with particles of indigo, and it is then plunged into the bleaching bath. This bath is composed of water and of the hydrosulphite liquor described above, prepared so that the bath will stand from 1° to 4° B. While the wool is passing through the bath, add a quantity of acetic acid equivalent to the hydrosulphite present. The goods must be properly worked in the bath, so that there may be no unevenness in the reduction of the indigo.—*Moniteur Scientifique.*

THATCH MAKING MACHINE.

One of the most attractive exhibits to agriculturists at the late Royal Show at Windsor was the thatch making machine of Barnard & Lake, of Braintree, Essex. Fig. 1 represents the machine as arranged for traveling. Fig. 2 shows it at work, the new feeding roller being seen carrying the straw forward to the needle, which greatly assists the man feeding the machine. A further improvement is a box for holding the string, which, as it is drawn from the box to the machine, passes through a compartment holding tar or any liquid with which it is desired to saturate the string as a preservative against weather and vermin. Fig. 3 shows the method of applying the thatch, when made, to the stack. Here we have a stack, with a roof, say, 36 feet long and 18 feet deep. The laborer (whom we will call the thatcher) begins by pitching the foot of his ladder about 6 feet from the end of the stack, and places it upon the roof, in a direction slanting to the right hand; the boy who assists him now brings up a 9 foot length of thatch, which the thatcher unrolls at the bottom of the roof, securing the end or gable with a "broach" or "springle" or a straight peg, whichever it is customary to use in the district. He then unrolls the bundle half way, puts another peg in, lifts his ladder, rolls the bundle under it, and leaves it as shown, with the third peg projecting. The next roll of thatch forms the second layer, and is treated in a similar manner, care being taken to cover the stitches of the first, and so he proceeds with each layer. When placing the last layer, he brings it higher than the ridge if it is to be left "hogmened," but if there is a ridging piece to be put on, it is only necessary to leave it level with the ridge.—*Iron.*

Fig. 3.—THATCH MAKING MACHINE.

Fig. 1.

THATCH MAKING MACHINE.

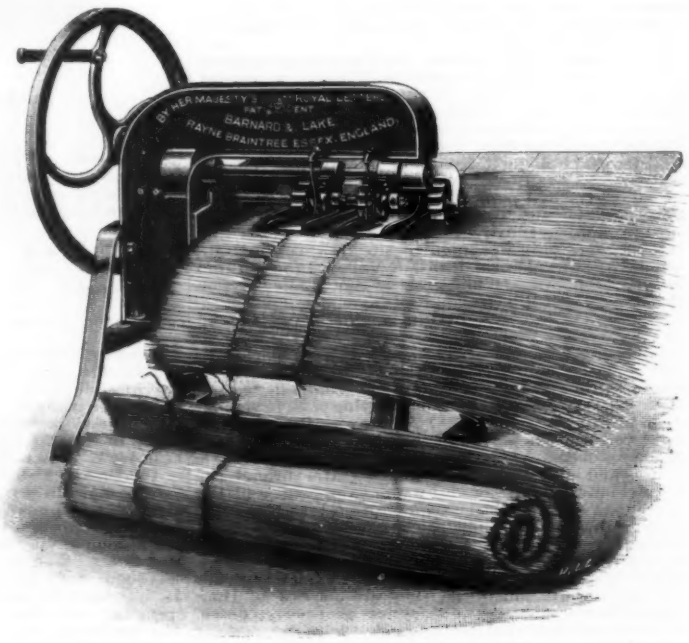


Fig. 2.

PHOTOGRAVURE PROCESSES.*

In general terms all practical photographic methods and processes depend on the action of light on one or the other of two substances. Light, under certain conditions, blackens certain salts of silver, and hardens certain organic substances, such as gelatine.

By the first action we produce our negatives and print our silver photographs; by the second action we produce printing plates from which we print with ordinary printing ink. The application of this second action is the foundation of the various processes of photo-mechanical printing. All of these depend, of course, on both actions of light—first, in the production of the negative; second, in the production of the printing plate.

There are four leading lines of photo-mechanical printing methods, photo-engraving, photo-lithography, photo-gelatine, and photogravure. Photo-engraving is understood in this country to mean "cuts to print with type." Photo-lithography is the process by which a stone is prepared for ordinary lithographic printing by photography instead of by hand. In both photo-engraving and photo-lithography the prints must be made in dots or lines, but by an ingenious device the half tone of the photograph is closely imitated. This is effected by breaking up the half tone into a series of very fine dots or lines.

The methods mostly in use by us are those which give a true photographic half tone. These are the photo-gelatine and the photogravure methods. The photo-gelatine process is known under a multitude of names: Albertype, heliotype, artotype, Lichtdruck, Indo-tint, collotype, are some of them, but they all mean the same thing, that is, printing from the surface of a layer of gelatine variously supported, and on which a printing image has been produced by light.

The *modus operandi* of obtaining such an image is, in its broad principles, simple enough. An ounce of gelatine is dissolved in, say, 10 ounces of water, at a temperature of 100° Fahr. To this solution is added forty to fifty grains of bichromate of potash and sufficient alcohol to make an easy-flowing liquid. This is flowed over a plate of glass or metal and dried in an oven at a temperature of 120° to 140° Fahr. on a level plate, so that when dry a very thin, even solution of bichromatized gelatine remains on the plate. The gelatine-coated plate is exposed to light under a negative, and now comes in the second action of light. The light passing through the negative hardens the gelatine in the shadows, partly hardens it in the half tones, and produces no effect where it is prevented from penetrating by the opaque parts of the negative.

The gelatine-coated plate, which now has the printing image produced on it, has only to be washed in water to prevent the further action of light, when it is ready for the press. It is inked up in the same general method that a lithographic stone is inked. But the sun has been the artist and has drawn the half tone of the photograph as no hand could have done it.

Photo-gelatine printing, to the reader and onlooker, seems to be the simplest thing in the world. On account of the "contrary" character of gelatine, it is in truth the most difficult, as those who have been longest at the work best realize. It will be seen that the reproductions by this process have a character all their own, and for a certain delicacy of result and true photographic effect they are unapproachable.

In the photo-gelatine process it will be seen that a new printing surface or material (gelatine) has been brought into use.

In photogravure, the oldest printing material (copper) and the oldest method of printing is employed, but the action of light takes the place of the engraver's tool. There is not time at my disposal to do more than briefly sketch the processes employed. The result desired to be obtained is an intaglio plate to be engraved by photography and to be used for printing on a copperplate press. In the photo-gelatine process we have described how a plate is coated with a thin, even layer of bichromated gelatine made sensitive to light. If we prepare this gelatine on a copperplate, and after the action of light place the plate with its light-produced image in an etching bath, it is evident that the etching fluid will penetrate the gelatine where the light has not acted, and where, therefore, the gelatine is not hardened. It will penetrate less where the light has hardened the gelatine slightly, and it will not penetrate at all where the gelatine is altogether hardened by light. In this way we have a plate etched more or less deeply, according to the gradations of the photograph, and, therefore, reproducing all the gradations of the photograph. This, very broadly, is the underlying principle of our process of photogravure.

Two essential conditions must be observed, however, in order to make the process practical. In the first place, in using a negative to print on the gelatinized copperplate, it is apparent that the picture would be a negative. Therefore a positive or transparency must be made from the original negative to print on the gelatinized plate, in order that the final picture may be a positive. The other necessity is that there must be a "grain" on the copperplate in order to give it an ink-holding capacity. This is effected by "laying a ground," as in the aquatint method, or by dusting the surface with resin or asphalt which is melted by heat—in both cases, of course, before the application of the gelatinous surface.

The etching fluid does not penetrate these fine points of resin, and the underlying copper is protected and remains in the shape of a number of minute pyramids, which prevent the ink being wiped out. The rest of the process of reproducing photogravure pictures is the ordinary method of copperplate printing, requiring, however, greater skill and care in its execution.

While photo-gelatine printing is marked by the delicacy of its results, the characteristic feature of photogravure is its strength and richness, which may be further heightened in the various steps of the process as well as subsequently by the hand of the graver.

Ernest Edwards.

* A communication to the Society of Amateur Photographers of New York.

Too much bearing surface may be a hindrance to a machine rather than a help. A United States naval vessel, some years since, had four-foot brass bearings on the shaft, which was some 13 inches in diameter. It was found impossible to keep them cool, and at last these bearings had to be reduced one-half in length.

THE ELECTRIC MAIL CARRIER.

A MODEL of a somewhat novel system of electric transportation was lately exhibited in operation in Boston, after which Professor Dolbear spoke upon the scientific points and aspects of rapid transit by such a device as was being exhibited before them at that time. He assured those present that the invention was worked out on the lines of scientific accuracy and complied with the exacting requirements or conditions of physical laws in being rendered useful in the service of man. He spoke of it as of great practical utility.

The inventor has availed himself of the well known attractive force which a helix or coil exerts on a rod of iron when placed near its center.

Thus, if a bar of iron or steel be placed with one end near the center of a helix, on passing a current through the latter, the bar will be drawn in and maintained in a central position as long as the current continues. If now the current be broken, the bar will again be free to move, and if we imagine a second helix placed in a position similar to that which the first occupied with relation to the bar, then, on the passage of the current through the second coil, the bar will be drawn toward that one and out of the first. With a number of helices arranged side by side, and an arrangement for making and breaking the current at the proper time, a bar of iron can be moved continuously in any desired direction.

Fig. 1 is a perspective view of a road intended to carry a small car for the transportation of small packages and letters. This rests upon a single rail and is guided by a small upper rail and the two upper flanged wheels. The body of the car (Fig. 2) is constructed of light steel. The car is arranged to pass between a continuous line of wire coils, which are completely covered and protected from the weather. The function of these coils and their operation will be readily understood from the examination of Fig. 3, which shows one of them with the covering removed so as to expose the contact arrangement by which the current is made and broken at the proper time.

The track constitutes one side of the circuit, which is connected through each helix to a contact point, C, and the other side of the main line conductor, L, is connected to the pivoted magnet, N S, whose function is to make and break the circuit of the helix at the proper time.

This is accomplished as follows: As remarked above, the car body is made of steel, which is magnetized. Thus, assuming the front of the car to be the S pole, the arrangement is such that just as the carriage is about to enter the helix, it repels the S pole of the pivoted magnet, N S, forcing it upward and bringing the N pole down in contact with the contact point, C. This closes the circuit through the helix, which therefore tends to draw in the car with a sucking action. This contact at C is maintained up to the time that the center of the carriage arrives at a short distance from the center of the helix, when the influence of the carriage on the magnet N S becomes neutralized and the contact is broken. It is evident that if the contact were maintained after the carriage had passed the center of the helix, the action would be to retard the motion of the carriage, and, indeed, to stop it altogether.

The object of breaking the contact a short distance before the center of the carriage reaches the center of the helix is to avoid the retarding effect upon the carriage which would be experienced on account of the extra current of braking in the coil. This extra current, being in the same direction as the main current, would tend to drive the carriage forward as long as it was behind the center of the helix; but it will be readily seen that if the carriage had passed the center, the extra current would tend to retard it in the same way that the main current would.

Thus it will be seen that each helix comes into action successively and only one is in action at any one time, so that the current is utilized to the best advantage. It will be understood that when once the carriage is in motion and its inertia has been overcome, comparatively little force will be necessary to maintain it at speed, and this is shown to be the case in the present system. As a result, the strength of the coils may be considerably diminished after a short distance from the terminal station, as the power required is diminished accordingly when the carriage has arrived at the proper speed. Another interesting fact in connection with the system is that the current in the helices is considerably reduced by the counter E. M. F. generated by the passage of the carriage through them, so that in a certain sense the system is self-regulating to maintain the carriage at its proper speed.

A system of this kind must necessarily be provided with means for stopping the car gradually and without

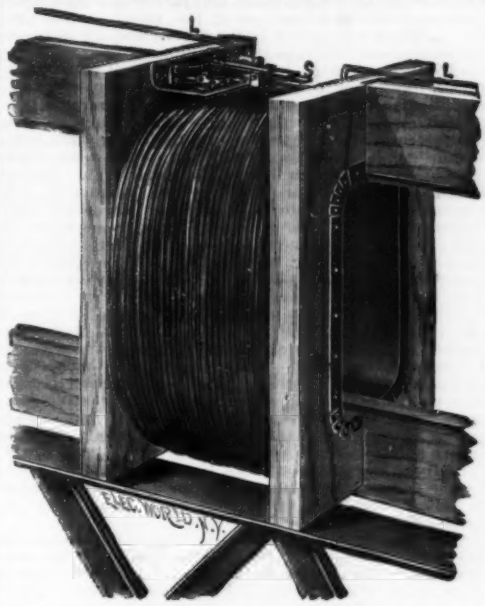


FIG. 3.—HELIX OR ENERGIZING COIL.

jar at a terminal station, and this has been worked out very ingeniously by the inventor. The brake consists of a helix similar to those shown, which is provided with a contact that, unlike the others, remains closed after the carriage has passed the center of the helix. The effect of this is that the car is retarded or pulled back, and it is astonishing, says *Modern Light and Heat*, to witness how rapidly a brake of this kind brings the car to a standstill. The system appears to be well adapted to the transportation of packages and letters and similar purposes.

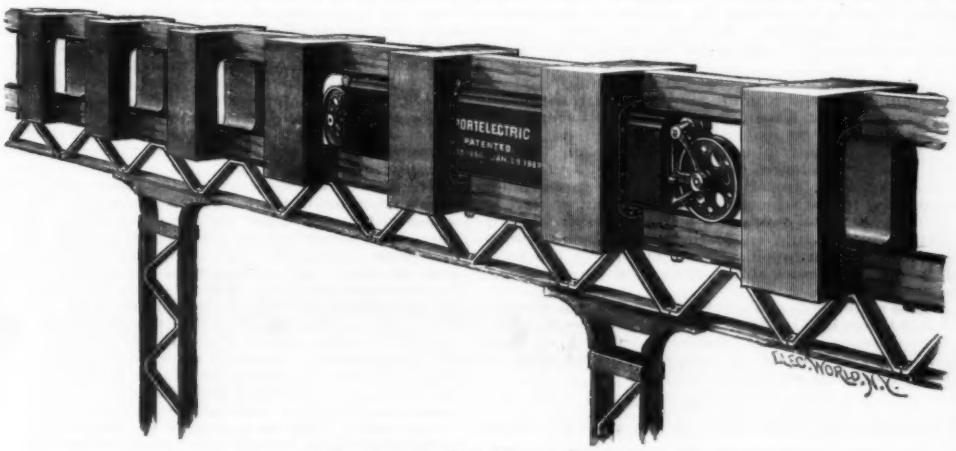


FIG. 1.—PORTELECTRIC TRACK.

FIG. 2.—STEEL PORTELECTRIC CAR.

ELECTROCUTION.

THE great many attempts which have been made during the last six months to influence public opinion against the employment of the electric current for capital punishment have not yet ceased. A great many interviews of so-called leading experts have been published; these experts have not only spoken in great horror against the use of the sacred (?) electric current for execution purposes, but they have also stated that in their opinion nothing was known up to the present time of the amount of current which will produce certain death Men having a good position in the electrical profession have actually admitted their incapability to tell approximately how much current killed the many people during the last few years who came in contact with charged electric light wires. Some experts have pretended to confound telegraph currents of small electrical energy with electric light currents of great electrical energy, and they say that almost every electrician in New York condemns Mr. Harold P. Brown's experiments, and does not consider these experiments a good basis for devising plans whereby human lives are to be taken.

It is astonishing to note that several well known experts, such men as Prof. Henry Morton and F. L. Pope, do confound currents of high voltage and only a fraction of an ampere with electric light currents of high voltage and many amperes. These gentlemen desire to make it appear that it is intended to kill the criminal with volts only, which means in fact, with no current at all. As is well known, the electrical energy does not consist of volts, but of volts × amperes. In the face of this knowledge, Prof. Morton and Mr. Pope, our electrical experts, speak of people who have had 10,000 volts pass through their body without having been killed; but these gentlemen forgot to mention that the current of 10,000 volts was most likely only one ten-thousandth part of an ampere, and that the total electrical energy was only about one watt, equal to one seven hundred and forty-sixth part of an electrical horse power.

As is well known, the volt represents merely the velocity of the current. Thus, a feather thrown from the Eiffel tower will kill no one, but a pound of iron thrown from the same tower would kill any human being it should happen to hit. The height of the Eiffel tower is the analogue of the voltage, and the feather and the pound will serve to illustrate different values of ampere.

This last illustration may also serve to explain why the lightning discharge of say 1,000,000 volts, and only a fraction of an ampere, representing, however, an electrical energy of a great many electrical horse power, does not always kill, but sometimes mutilates the victims. This latter fact has been put forward by the learned (?) experts as a proof for their arguments that the electrocution current may not always kill. These men forgot that the lightning discharge never seeks human beings, but the currents generated in the clouds seek the nearest ground to discharge, or to combine with the earth currents, hence the killing of the victim depends whether he is directly in the path of the discharge or only near it; in the latter case he will receive merely a shock or he will be mutilated, in a similar manner as the pound of iron thrown from the Eiffel tower will kill a person if it hits him right upon the head, and only mutilates him if it strikes a part of the body.

Do the people interested in the speculative and dangerous high voltage alternating electric light system think they can dumfound knowledge and facts? Has Mr. Brown used alternating electric light currents of many amperes during his experiments? or has he used induction coils, or so-called medical current or lightning discharges? Since he, for obvious reasons, has not used the last mentioned sources, why, then, do these experts try to mislead the public?

What has the fact that both continuous and alternating currents of high voltage and many amperes are dangerous, to do with the question at issue: Which of the two is the most suitable system to serve electrocution? And that there cannot be the least doubt that an alternating current of an electrical energy (such as proposed) of 1,500 to 3,000 volts and of from ½ to 1 ampere will produce a most certain and instantaneous death, I shall now explain.

The several hundred people who died during the last few years by accidentally putting themselves in an electric light circuit have been killed with a current of from 800 to 2,400 volts. The average resistance of the human body is from 5,000 to 30,000 ohms—depending upon the largeness of the contacts between the body and the conductors and the physical condition of the individual. Now, however many amperes were generated or flowing in the circuit at the time of the accident, according to the well-established Ohm's law $\left(C=\frac{E\,M\,F}{R}\right)$ not more than from $\frac{1}{10}$ to $\frac{1}{20}$ ampere could have passed the victim's body, representing at the utmost an electrical energy of less than two electrical horse power.

I shall now show that during Mr. Brown's experiments much smaller values were used, and I shall show with a few calculations that nothing was concealed by Mr. Brown, as has been charged to him by some of the experts (?) From the great number of experiments made in December, 1888, by Mr. Brown, in presence of the committee of the Medico-Legal Society and their chairman, Dr. I. Mount Bleyer, I will select the following two cases:

1. An alternating current of 700 volts killed a horse weighing 1,230 pounds. The resistance of the animal was 11,000 ohms, measured after good contacts had securely been fastened to the animal. The experts pretended not to be able to tell how many amperes were used! As before said, electric light currents of many amperes were used. Consequently, according to Ohm's law, the following simple calculations give the amperes used:

$$\text{Amperes}=\frac{\text{volts}}{\text{ohms}}=\frac{700}{11{,}000}=\frac{63}{1{,}000}\text{ of an ampere}=\text{total electrical energy}=\tfrac{1}{18}\text{ of an electrical horse power.}$$

2. An alternating current of 750 volts killed a calf weighing 145 pounds. The resistance of the animal was 1,300 volts, which gives the following value in amperes:

$$\text{Amperes}=\frac{\text{volts}}{\text{ohms}}=\frac{750}{1{,}300}=\frac{58}{100}\text{ of an ampere}=\text{total electrical energy}=\tfrac{1}{18}\text{ of an electrical horse power.}$$

Not satisfied with their charge of concealing, these experts quoted the case 21 of Mr. Brown's experiments, relying upon this case to prove that the electric current may not always kill. However, the experts apparently never made any calculations, otherwise they would have discovered that the electrical energy was too small to kill any dog, and that such experiments have also to be made to prove the limit on this side of the question. In the case 21 the resistance of the dog with the contacts was 200,000 ohms with 100 volt alternating current; hence the whole electrical energy which passed through the dog was only $\frac{1}{1000}$ part of an electrical horse power. With enlarged contacts the resistance of any human being or animal can easily be brought down by from 2,000 to 5,000 ohms.

The current to be employed for electrocution has been settled to be from 1,500 to 3,000 volts and from ½ to 1 ampere. I suppose the public at large does not know the value of a current of 3,000 volts and 1

ampere. It represents a force equal to over four horse power. In olden times the power of four horses was used to quadripart the criminal. In the last method, "hanging," the criminal himself had to supply the motive power for dislocating his neck or strangling himself to death. This last, most uncertain and repugnant method was abolished by humane legislation, and superseded by the neat and scientific method of sending the energy of from two to four electrical horse power through the criminal, however, not to tear his flesh and bones asunder, no external violence is intended, but the more certain internal destruction will take place! The current paralyzes the criminal's brain and spine, it stops the action of the heart and respiration, it arrests the circulation of the blood, the latter becoming decomposed by electrolysis, the albumen coagulates and the blood turns black in color. The current disorganizes all tissues in the body, whether they are heretrologous or homologous. All these complex actions of the current take place instantly and at the same time, which, in other words, kills the criminal instantly, without pain, disfigurement, or mutilation.

To prevent failure the electrocutioner must employ contacts of sufficiently large size, so as to reduce the criminal's resistance to the number of ohms which will allow the whole electrical energy to pass through his body. Thus when a current of 1,800 volts and $\frac{1}{6}$ ampere is employed, the criminal's resistance must be reduced to 3,000 ohms, in accordance with Ohm's law,

$$\text{which says ohms} = \frac{\text{volts}}{\text{amperes}}$$

With the alternating current proposed to be used, the deadly tetanic contractions of the nerves are 300 times per second intensified, and however a person could be found with a constitution to withstand, at the utmost, the action of a continuous current of 3,000 volts and $\frac{1}{10}$ of an ampere (about $\frac{1}{6}$ horse power), no living being could withstand such a current vibrating at the rate of 300 times per second. In fact, $\frac{1}{6}$ of the electrical energy proposed to be employed must bring certain and instantaneous death to any human being, however strong and hardened his constitution may be. The strongest nerve system must succumb the quickest.

The Stevens case, reported from Boston, fully proves that the electrocution current is amply sufficient and excludes all uncertainty as to its deadly action. Mr. Stevens accidentally took hold of the two brushes of an 1,800 volt dynamo, and was nearly killed—he stated erroneously that a current of 50,000 candle power (?) had passed through his body, which would have amounted to an electrical energy of from 10 to 20 horse power. Taking the resistance of Stevens body as small as 10,000 ohms, not more than an electrical energy of $\frac{1}{12}$ of a horse power could have passed into his body. Had it been an alternating current vibrating at the rate of 300 times per second, the man could not have recovered, and I think Mr. Stevens will agree that an alternating current of double the voltage and many times the electrical energy would have kept him on the other side of the great mystery without having felt any pain and without ever having known how he left this electrical world.

In regard to the question whether an alternating current is more dangerous than a continuous, I must say that a current of 3,000 volts and one ampere is not less dangerous than such an alternating current. But the latter can commercially be delivered to the public only at such and much higher voltage. On the other hand, a continuous current can be delivered at a very low voltage.

The same electrical energy of the electrocution current of 3000 volts and 1 ampere can be delivered to the public say of 100 volts and 30 amperes. If a person comes accidentally in contact with this source, not more than about 1-100 part of an electrical horse power can pass the human body against the severed horse power of the high voltage alternating current. To kill a criminal with a current of 100 volts and 30 amperes, he would have to be placed in two closely fitting copper receptacles, inclosing nearly one half of his body, and by this means the resistance of the body could possibly be reduced to 3 ohms, when the whole electrical energy of the four horse power would also pass the criminal's body and death would also be the result, though not so quickly as with the alternating current. Whether the resistance of the criminal can be reduced as low as 3 ohms by means of the copper receptacles, I cannot tell. I have merely quoted it as an illustration showing that the resistance of the human body must be reduced to 3 ohms to kill in the case of the continuous current as supplied to the public.

CHARLES T. HEINRICHS,
Electrical Engineer.

New York, June 18, 1889.

UNDERGROUND ELECTRIC CABLES.

AT a meeting of the Institution of Electrical Engineers, London, not long ago, Prof. George Forbes, F.R.S.S., read an interesting paper entitled "Some Electric Lighting Central Stations in Europe, and their Lessons." In this paper the author gives the results of his electric observations in Berlin, Milan, Rome, and other places. He reviews and describes the various conductors, electric machines, appliances, and methods of working in the different places visited. In regard to conductors he is very pointed in his condemnation of the class used in Berlin.

The following are abstracts of his reported language, as given in the *Journal* of the Institution:

"The next point which I wish to draw special attention to in connection with the Berlin central station work is the type of cable which I have now described. This cable succeeded very well for three years, but lately they have been giving way very generally. The lead gets eaten into and water percolates to the copper, which is then destroyed. At first it was supposed that the deterioration came from the cable being pierced by the borers used by the gas people, but it was found that the same fault is produced even in iron pipes which have remained uninjured. It is supposed that the deterioration of the lead may be due in some way to its forming a galvanic element with the iron sheathing. Whatever the cause may be, the fact seems to be established that such cable will not stand underground electric light work for more than about three years. These cables generally run under the footways without any casing, and are connected by circular junction boxes to the houses, powerful clamps and no soldering being used for the contacts."

Again he says: "We have now to consider a very important, and perhaps the most difficult, part of the problem of central station lighting—How are we to preserve our insulation? It must be noticed that we do not require a high insulation for the sake of getting a small loss of current, but only because with many insulators the high insulation is more permanent, and permanency is the quality of insulation which is most to be desired. I am not going to discuss at present the whole question of insulation, but rather to draw conclusions from the experience of the past. At the present moment vulcanized India rubber and okonite are the substances which have the highest reputation for durability and high insulation under all conditions. These, like other cables, are sometimes covered with lead, but in their case it is only as a mechanical protection, especially during the process of laying, because the destruction of the lead would not destroy the insulation. Of late years a class of cables has been much praised, about which I wish to speak. The copper conductor, stranded or otherwise, is covered with any fibrous material, preferably jute, impregnated with bituminous oils. This covered core is inclosed in the lead pipe. In this class of cable the insulation depends upon the lead being water tight. We all know of many places where this type of cable has done good work for a limited time, and many of us were inclined to believe that it was quite satisfactory; but I think I am right in saying that none of us know of its having worked successfully in any place for three or four years. I have said that a cable of this kind has hitherto been exclusively used in Berlin, the lead being covered with layers of tape or braid soaked in a preservative compound, and the whole armor plated with two closed spirals of iron ribbon. I regret to have to tell you that this insulation has been a failure. It goes on well enough for about three years, then the lead gives way, the covering on the copper is permeated, and chemical or voltaic action sets up in the copper, which itself becomes disintegrated.

"So far as experience goes, this type of cable seems to me to be unsuitable for permanent work with the electric light. I trust that in the discussion we shall have some facts brought out. I had hoped, from what Berthoud & Borel, and also Waring, had done, that this would not be so, but the Berlin experience leads me to think otherwise; and on looking through the testimonials of makers I do not find that these cables, when placed underground, have ever worked electric light circuits satisfactorily beyond the three years fixed by the Berlin people as being destructive. I have been told, but I cannot believe it, that there is one company in London actually proposing to put such lead-covered cables without covering into iron pipes. Of course every one knows they would soon be eaten into by galvanic action.

"At Berlin and elsewhere I believe there is the intention of trying some modification of the system of using bare conductors, first practically used by Mr. Crompton at South Kensington. Taking economy into account, it is probable that for low tension circuits this is an admirable plan. It is probable that it may also be adapted to high tension circuits by using oil insulators to support the bare conductors. When copper strip is used, it is necessary to raise the cover of the trough in order to increase the number of conductors; this is very expensive. For my own part, I would prefer a drawing-in system, if it were otherwise equally good.

"No information has ever been given as to (1) the maximum or (2) the minimum insulation resistance of the conductors at Kensington Court, but perhaps this information will be given during the discussion.

"At the present moment it seems to me that the only types of underground cable proved suitable for permanent work are either bare copper supported on insulators, or else vulcanized India rubber, or perhaps okonite. Especial care must be taken to avoid an insulator which is injured by the gases which permeate the soil of a town, or which has the property, like pitch, of becoming viscous, and so letting the copper become decentralized."

These statements of Prof. Forbes were made the basis of an address by Dr. Werner Siemens before the Elektrotechnischer Verein of Berlin, on the 29th of March last. We give herewith a translation of the same and of the discussion which followed:

[ELEKTROTECHNISCHER VEREIN.]

UNDERGROUND CONDUCTORS IN ELECTRICAL PLANTS

By Privy Councilor Doctor WERNER VON SIEMENS.

GENTLEMEN: The well known English electrical engineer Prof. George Forbes delivered, February 28, in the English Institution of Electrical Engineers, a lecture on "Some Electric Lighting Central Stations in Europe, and their Lessons." In entering this subject, he apologized for doing so by emphasizing the fact that even in England much might be learned from those who had been in a position to gather experience in regard to this subject earlier than the English. Mr. Forbes on his tour to Berlin, Milan, and Rome learned many a point which he readily acknowledged as a progress in this field. That he himself was struck by what he saw may be inferred from his own words. Speaking about the Berlin central station, he says:

"It struck me that the working of this station was thoroughly German—certainly not American—but it was most methodical and very effective." In Berlin, the birthplace of the underground conductors, the dynamo, the electric railroads, and innumerable other electro-technical achievements, his astonishment seems rather remarkable. Mr. Forbes and his countrymen must, I dare say, familiarize themselves with the idea that the time is past when England's superiority in mechanical engineering controlled the world, and that now beyond the sea, surrounding and protecting England, valuable technical achievements are to be found! Mr. Forbes says at the beginning of his address that "the object of his paper is" to raise a "discussion on the details of central station lighting and electrical distribution, and to enter a protest against defective systems." Unfortunately, however, without having sufficiently informed himself, he commences this useful discussion with a protest against the system of iron-armored lead cables which he found in the three cities visited by him.

He rests his condemning judgment exclusively on experiences obtained in Berlin with this system of conductors, summing up his opinion as follows: "These cables succeeded very well for three years, but lately they have been giving way very generally. The lead gets eaten into, and water percolates to the copper, which is then destroyed. It is supposed that the deterioration of the lead may be due in some way to its forming a galvanic element with the iron sheathing. Whatever the cause may be, the fact seems to be established that such cable will not stand underground electric light work for more than about three years." One would suppose that such an eminent electrician would pronounce such a hard and condemning judgment upon such an extensive system only after very close and thorough investigation. But nothing of the kind is to be found in Mr. Forbes' lecture. He bases his judgment in the first place, as stated, upon the unfavorable experience gained in Berlin, for the communication of which he records his thanks to Mr. Rathenau and Mr. Datterer, of the Allgemeine Elektricitats-Gesellschaft; and secondly upon the unfavorable experience hitherto obtained with lead-covered cables of different manufacture in England and America. In no case, he says, a lead-covered cable ever worked satisfactorily beyond three years, a period fixed by the Berlin people at which the destruction begins.

I must here express the hope that the Berlin electrical engineers alluded to were misunderstood by Mr. Forbes, and that for their own justification they will give a public declaration to this effect, as the statements attributed to them do not at all agree with the facts. As a matter of fact, the Berlin system of conductors, manufactured and placed underground by the firm of Siemens & Halske, has a length of about 130,000 meters (a little over eight miles), of which about 51,700 meters were laid in the year 1885, while about 86,400 meters were placed underground in the year 1887–88. The first portion of these cables, being buried now three years and a half, is still unchanged. Neither an oxidation of the lead pipe nor a deterioration of the insulation has been observed.

The iron armor, coated with an asphalt compound and a layer of three millimeters of tarred jute, shows likewise no change or alteration, as has been proved only lately by digging up the cables at about forty different places of the Berlin network. Defects in the cable system did not make their appearance until the month of August of last year, soon after the electric connection of the three divisions of the underground system had been accomplished, and were found exclusively in cables which had been placed underground in the years 1886 and 1887. Unfortunately, the existence of these defects was not discovered—at least they were not reported for repair—until a complete destruction of the defective cable had taken place by its fusing together with adjacent cables. Defects were found at four places and removed by the substitution of about 200 meters of new cable. This was done within a few days, without interfering materially with the working of the system. The insulation of the entire network was thereby restored, and since then no new defect appeared, as recently declared by Director Rathenau, in answer to direct questions. Among the defects found were two, as can still be seen, caused by an external injury, being cut into with a pick. In the other cases the destruction had advanced so far by fusion that the first cause of the defect in the insulation could not be determined.

That the iron armor around sections of cables adjacent to the faults was eaten into by galvanic action is the natural consequence of the fusion of copper, lead, and iron near the burnt-out place.

The renewal of all the cable pieces of which the iron sheathing had been thus corroded accounts for the disproportionally large amount of cable—200 meters, about—required for repairs.

Mr. Forbes has overlooked the circumstance that such a corrosion of the iron by the current in the cable necessarily had to take place as a secondary effect of the defects which had arisen, and erroneously assumes that such destruction was the primary cause of the fault produced by a difference in the galvanic tension between lead and iron. When he says that lead would be galvanically destroyed by contact with iron, it is likely an error due to haste, since, on the contrary, lead, according to the position it occupies in the series of tension, is protected from oxidation by its contact with iron, while iron is destroyed. Such a destruction of the iron, however, would have no influence upon the preservation of the lead, hence upon the insulation of the cable. But as a matter of fact, as the cable is constructed, no contact takes place between the iron and the lead. These metals are carefully separated from one another by means of a layer of asphalted jute, three millimeters in thickness, and their insulation from each other is constantly examined. It is, therefore, an error on the part of Mr. Forbes to suppose that the difference in galvanic tension between lead and iron can be the cause of the destruction of some short pieces of cable in the Berlin system. This is further confirmed by the fact that wherever the iron sheathing (which itself is protected by a coating of asphaltum and finally by a cover of tarred jute about three millimeters thickness) was dug out, it appeared entirely unaffected, and—as a rule—it even had the same appearance as before it was laid. As already stated, the Berlin cable system, with its many branches and house connections, has, unfortunately, not been laid so that regular measurements of the insulation of the whole network and its parts can be taken as a rational operation of the system would demand, without materially interfering with the service. Only to the lack of insulation tests must be ascribed the cause that these faults could grow to such destructive proportions. For this very reason, I am sorry to say, it could not be ascertained whether the original high insulation of the whole system remained unchanged. It is, however, possible that several faults may still exist, which must yet further develop themselves before they can be noticed and repaired. That there is no cause for the assumption of a more general essential decrease of the insulation is shown by the measurements made in cables of the same construction laid by the firm of Siemens & Halske at other places. Thus ten cables of a like construction and of a total length of about 1,688 meters, laid at Munich in the year 1884 for lighting the theater, were examined on the 9th March this year. Nine of these cables showed on the average an insulation of 50 megohms per kilometer, while

one showed a considerably lower insulation, which, however, has not yet made itself felt. Immediately after these cables had been laid they had an average insulation of 160 megohms per kilometer. This decrease in the insulation, which from a practical point of view may be disregarded, is however only apparent, since the terminals of the cables, located in moist, unheated rooms, could not be dried and insulated with such care as the measurement of such high insulations would require. These cables, now in use for five years, are rather a striking proof of the incorrectness of Mr. Forbes' assertion that the iron-armored lead cables render only a three years' service and then are ruined, owing to the destruction of the lead! How untenable and without any foundation this statement is throughout can be seen from the figures already given with regard to the Berlin system of conductors; for, notwithstanding the neglect of testing the insulation, whereby small defects were allowed to develop into extensive breaks, only about ½ per cent. of the total length of the Berlin cable system was employed in the necessary repairs. It is entirely unjustifiable therefore to draw the conclusion that iron-armored lead cables are to be regarded as a failure. With much greater justice this assertion can be offset by the other, that the results in the use of such cables in the central stations of Berlin, Munich, Rome, Turin, Milan, Mulhausen, Elberfeld, Darmstadt, Geneva, Salzburg, Lyons, Hague, St. Petersburg, Moscow, etc., have furnished the proof that this system has shown itself to give entire satisfaction and to be beyond doubt at this moment the best, most reliable, and most durable of all systems of underground conductors hitherto in use for central stations. It is, however, possible that even in these cables faults may occur, caused either by external injuries or by mistakes made in manufacturing or laying them. For this reason a system of cables, as well as any other piece of engineering, requires constant inspection, and provision should be made to facilitate the necessary tests.

Mr. Forbes, as an additional support of his condemning judgment pronounced on lead cables in general, alleges that lead does never remain sound underground and that in none of its numerous applications both in England and America a longer period of duration has resulted. If this be true, it only proves that in those countries the correct principles in constructing, manufacturing, and laying lead cables have not yet been observed. In Germany we have made extensive experiments and trials with lead cables for a generation, and have also earned many a sad experience with the same. When electrical conductors, laid underground on an extensive scale throughout Prussia in the years 1847 to 1850, insulated only by gutta percha without any external protection, were ruined chiefly by field mice, rats, and other gnawing animals, it was first attempted to give them an external protection by a lead mantle; but this attempt failed, as the animals even gnawed the lead. In this instance the fact was also established that generally the lead preserved itself very well in the soil, so that even now, after more than forty years, pieces of lead conductors are frequently dug out in a perfect state of preservation, but that in some particular spots the lead was completely destroyed after a very short time. An investigation of this phenomenon brought out the fact that wherever decomposing vegetable matter, such as wood or other similar substances, came into direct contact with the lead, the latter is quickly converted into carbonate or acetate of lead, when the air has access to it; while it remains unchanged for thousands of years in soil which is free from organic matter, as the remains of the Roman aqueducts prove, which even to-day are found in an unaltered condition. Hence it was found necessary to protect the lead pipe carefully, throughout its entire length, from contact with moulding organic matters, which was the more difficult as it was found that also a bedding in lime or cement was deleterious to the preservation of the lead. It is the result of many years' experimenting that taught us the fact that a coating of asphaltum over the lead and thereon again a wrapping of asphalted fiber, such as hemp or jute, forms an entirely reliable separation. This protecting wrapper of the lead, however, required itself a protection against external injury by men and animals. As the drawing of heavy and not very flexible conductors into iron pipes over long distances is not practicable, and the placing of them in iron or masoned conduits, besides being very costly, was found only successful when the latter were accessible to men, we arrived at the conclusion that a double spiral of sheet iron tape, which again is protected against oxidation by asphalting or galvanizing and covered with a wrapping of tarred jute, forms the most suitable protection.

Extensive tests throughout a great number of years have demonstrated that in this manner conductors can be produced which will keep in all sorts of soil for an unlimited space of time, if the soil is not impregnated too much with decaying animal matter. It is of course essential for the maintenance of a perfect insulation that the fibrous wrapping separating the copper strand from the inside of the pipe be thoroughly impregnated with a highly insulating substance filling every pore with the impregnating mass, and that the lead pipe itself be absolutely tight and free from pores. Experiences dearly bought have taught us that this cannot be reliably attained by the ordinary lead pipe presses, where the lead is heated to the melting point. Owing to impurities of the lead and to little air bubbles, tiny channels are formed here and there in the lead, through which water in the course of time percolates to the insulator. By pressing an additional layer of lead around the first one the duration of its usefulness was materially prolonged, but the evil could not be fully removed thereby, as the water, having found its way through a defect in the external pipe to the intermediate space between the two lead pipes, spread within the same, until it reached a flaw in the internal lead pipe. We have succeeded, however, in manufacturing perfectly tight lead coverings by pressing the lead *in a cold state* and under a very high pressure around the insulated copper strand. By the enormous pressure thus required, any air bubbles which may be still contained in the lead block are reduced to a harmless minimum, and as a single lead mantle permits of a greater thickness to be given it, it is not likely that minute solid impurities will extend through the whole thickness of the lead mantle. But should it nevertheless ever occur, it is the province of the thorough electrical tests in the course of manufacture to recognize and remove such faults. To accomplish this, and also in order to be able to detect during the subsequent regular electric tests of the cable system the existence of faults in their first stage of development, as high an insulation as possible is required, although for practical purposes such a high insulation is entirely immaterial.

Against the above described method of constructing cables, generally applied by the firm of Siemens & Halske, the objection might be raised that asphalted jute, as a separator between the lead and the iron sheathing, in the course of time might bring about a decomposition of the lead pipe by means of the jute decaying in spite of being impregnated with ashpaltum, and thereby cause the formation of carbonate or acetate of lead. This objection might be met by the substitution of asbestos for jute; but as many years' experience affirms the permanent preservation of jute fiber soaked in asphaltum, the use of the costly asbestos was thought to be dispensable.

As another drawback to the system of lead cables just described may be mentioned that the double iron sheathing cannot be made strong enough to exclude completely any injury to the cable from the tools of the men working in the soil of the municipal streets. This objection must be recognized as just, for, although the tight iron sheathing may happen to be pierced only in rare and extraordinary cases, it is nevertheless too elastic and pliable to prevent in all cases the insulating fiber between copper and lead being disrupted or squeezed apart. This makes it necessary to exercise a very careful control over all ground work in the vicinity of cables, and to supply an additional external protection against violent injuries at exposed points by means of covering the cables with plates of iron or stone, or by inserting them in conduits. It is expedient to fill the latter with gravel or sand in order to keep the cable always in a moist condition, so that any defects or faults can be noticed at once.

As a further disadvantage of the use of insulated cables for the electric conductors of central stations may be cited that, by a defective construction of the network, or by mistakes in its use, it may easily occur that parts of the same may get overheated at such a rate that thereby the insulation of the conductor is destroyed. It is for this reason that gutta percha, and generally all such substances which by an increase of temperature are liable to soften, melt, or decompose, should not be used as insulating material for such conductors. The lead cables distinguish themselves above all other underground conductors for being able to sustain a very high degree of heating without any harm whatever. You see here among the pieces of cable exhibited one piece which was taken out of the Berlin system during a repair, and which, by the fusing together of earth particles with the jute covering of the cable, furnishes proof that it has been exposed to an extremely high degree of heat. Nevertheless the insulation is entirely unimpaired. But it is not inconceivable that the heating under particularly unfavorable circumstances may reach a point where the jute, separating copper and lead, may get carbonized, and thereby become conducting, or that products of distillation appear which render the layer of insulation conducting or even exercise a destructive action by mechanical pressure. For these very reasons, an underground system of conductors requires a greater degree of care during its construction, control, and use than an overhead one or a system of conduits in which bare wires are placed on insulators.

Such a system, however, is available only for currents of low tension, and even for those only under particularly favorable conditions. In populous cities, in which the ground of the streets has already been occupied for various purposes, it will be possible only in rare instances to establish sufficiently accessible and always dry conduits, unless the same, as the Paris "egouts," were formerly constructed for other purposes. Unfortunately, the modern larger cities are mostly not in a position to construct such a system of accessible conduits under the street level, and frequently, as in Berlin, the nature of the soil and the conditions of the ground water form an obstacle, and also sewers and conduits of all descriptions intensify this difficulty. The tendency of our social development, the ever-growing concentration of people in great centers of traffic, will presumably bring about the unavoidable necessity of releasing the surface street traffic by a second means of transit either underground or overhead, in which then the electrical conductors may find a place. Until then we will have to content ourselves with finding the necessary room for insulated conductors, with the best possible protection against external injuries, within the soil of our already much occupied streets.

This is in substance what I had to communicate to you. I have preferred to read it to you from my manuscript, as many statements, even accusations, if you will, are to be found therein which require an exact rendition. It is to be hoped, as already said, that the unheard-of verdict which an English engineer of high rank renders in the presence of the first and oldest society of electrical engineers of the world, without having fully informed himself, will become known. I myself introduced him here to the gentlemen of the Allgemeine Elektricitats-Gesellschaft, but he has not called on me since. It would surely have been very easy for him to procure the necessary information, particularly after having received such a very unfavorable impression. I concede that this is a polemic address biased a little by business interests; but I think, gentlemen, we can and must learn from the English this one thing: to defend our rights sharply, especially against such foreign and reckless attacks lacking all foundation as was this one; and I hope that the Institution of Electrical Engineers of London will not refuse to insert this address in the columns of their paper.

I have brought with me a few samples of cables which, perhaps, may prove interesting in so far as they show the mighty destruction which sets in in such cases. The heavier ones, which are difficult to transport, I have not here. As stated above, such destructions have taken place, and naturally adjacent cables have in many places been affected, so that quite a number of injuries has been found. For those gentlemen taking an interest in the matter, I have, speaking today of cables, exhibited here also samples of cables of various sizes, for low, middle, and high tension, which will give you a general idea of our system of conductors.

I do not mean to say thereby that not just as good and durable cables could be made in a different way; but I am compelled, answering this sharp and condemning judgment of the English engineer Forbes, to state the reasons which have led us to make better cables, cables not liable to those defects observed by him in England, which made him say that lead cables would keep only three years, and from this point of view, I beg you to accept my defense.

Honorary President Dr. Von Stephan—I tender thanks to the speaker in the name of the assembly for his interesting and instructive address, the extraordinary importance of which will certainly not escape the notice of any one present. With the last statement, that it is our duty to vindicate our rights of priority, and also perhaps of better practical manufacture, against incorrect representations and disparaging judgments, this whole assembly will, I think, agree.

I ask now for a general discussion in relation to the address just delivered.

Director O. Von Miller—

Gentlemen: The Privy Councilor Von Siemens has desired a declaration as to how far the allegation of Professor Forbes may rest on an erroneous conception of the communications made to him. Unfortunately, Director Rathenau, to whose statements Privy Councilor Von Siemens makes reference, is not present, but I can safely say for him and in his name that the information given by him to Professor Forbes must have sounded differently from that verdict alluded to and repeated here by Privy Councilor Von Siemens, according to which all lead cables were destroyed after a three years' use. If Mr. Rathenau or myself were convinced that the cable system of the Berliner Elektricitats-Werke would keep only for three years, we would be bound to place their value almost totally to our debit in the balance sheet; this we have not done, as we are convinced that a general destruction of the network in Berlin will not take place in the near future. If we should regard the iron-armored cables to be in all cases as perishable as that, we would certainly not again use these cables for underground lines to be constructed within the near future, as we most likely will do, at least until we have concluded the necessary preparations for the manufacture of a new underground system already tried by us, and have completed the necessary time tests. As for myself, I share the opinion of Privy Councilor Von Siemens that there are many instances in which a lead cable will keep well. Certainly a long durability of the cables may be anticipated if, for instance, the conditions are so favorable as they are at the electric station in Munich, mentioned by Privy Councilor Von Siemens. Here the armored lead cables covered with sand and protected by layers of bricks are laid in a street composed of coarse gravel, which is seldom if ever disturbed by excavations, and in which there are no gas pipes running alongside the cables. Here in Berlin also, owing to a sandy subsoil, the conditions seem particularly favorable for lead cables. Nevertheless, there are, as experience has taught us, also cases in which lead cables are destroyed without the intervention of extraordinary causes. In the course of last summer there occurred five such cases which I would like to mention briefly in order that, by a public discussion which, I hope, will extend beyond our limited circle, as many experiences as possible may be brought out in regard to the important subject of underground conductors. In one case evidently the iron-armored lead cable was injured by the stroke of a pick, so that the cause of the trouble was obviously due to insufficient protection by the iron armor. A second lead cable which lay in an iron pipe under a street crossing showed a short circuit between lead and copper, without the protecting iron sheathing being injured. An external injury could not have been the cause in this instance. The cause must have been either phenomena of induction or electrical discharge, or else a fault caused in the making of the cable. Of the other three injuries, one was discovered in the street "Unter den Linden," one in the Friedrich-Strasse near the Cafe Bauer, and one in the Friedrich-Strasse between Mohren and Tauben Strasse. At each of these places the lead cables with their covering were fused to such an extent that the primary cause of destruction could no more be determined with certainty. The opinions on this point varied a good deal, and it was thought not to be beyond the possibilities that an electrolytic action had set in between lead and iron as a consequence of infiltration of organic acids. But even at that time it was considered to be more probable that chemical actions caused by organic substances, the injuriousness of which Privy Councilor Von Siemens just mentioned, may have produced the destruction of the iron and lead. The probability of this supposition finds a corroboration in the fact that also at Munich, at a corner where certain organic acids happen to be, the lead cables are very rapidly destroyed, and that also in gas works and in the neighborhood of hospitals, as demonstrated itself in a number of cases, lead cables do not last any great length of time. To prevent the action of the acids and salts which are found in cities, the cables newly laid in the Friedrich-Strasse, Berlin, by the firm of Siemens & Halske were bedded in a thick layer of clay. According to later suggestions by Siemens & Halske, the lead cables should be placed in a sand bed 30 centimeters deep and covered by a layer of hard-burnt bricks for protection against mechanical injuries. This expedient has not proved satisfactory in the Leipziger-Strasse, as the different street laborers, who have always to dig below the electric cables, removed both the sand and the bricks from their original place.

The periodical electrical measurements of the cables, which are considered absolutely necessary by Privy Councilor Von Siemens, would not prevent the mechanical and chemical destruction. They might, perhaps, serve to diminish the extension of the existing defects or faults, but I do not know how in large central stations to which several thousand consumers are connected such measurements could be performed, necessitating the disconnection from the houses. Many consumers would not agree to this, and for that reason, indeed, a portable battery of accumulators as proposed by Siemens & Halske would have to be kept ready for temporary lighting of disconnected houses. But such complicated arrangements I consider as impracticable when thereby only a fault can be ascertained, while the cause of the evil cannot be prevented. Now, whatever may have been the cause of the trouble, whether mechanical or chemical influences had a greater share, at any rate,

according to our experiences, it was necessary to try if, perhaps, other kinds of underground conductors might be constructed which, consisting of materials more durable in the soil than iron sheathing and lead, would not be subjected to such troubles as experienced at Berlin. To this end we have made experiments to attach copper rods to insulators, similar to those for telegraph conductors, and to fasten these insulators in small underground conduits. At the beginning of this year such a conduit has been laid in the Zimmer-Strasse to a length of 300 meters. This conduit is made of the well known "Monier mass;" but for this purpose other materials may also be applied, and we have made already experiments in this direction with other building materials. The insulation of these conducting rods kept very well, being according to recent measurements 13 megohms per kilometer. The dimensions of the conduit are such that 15 conductors can be placed in one channel of a square section of 25 cm. × 25 cm., and consequently it is possible to lay them in all the streets of Berlin. The cost of the insulation for a cable system of such size as that used in Berlin will be from 20 to 40 per cent. cheaper than if lead and iron armor is to be used.

I think, therefore, that either this or some similar system of conductors will certainly find a far-spread application.

Mr. Wilhelm von Siemens—I would like to beg leave to enter into a brief discussion of some of the statements made by the last speaker.

He says that a defect had been formed even in a cable drawn through an iron pipe, and that an external injury could not have taken place in this case. Against this assertion must be observed that in the protocol drawn up by the firm of Siemens & Halske in regard to the damage caused, the note is to be found that one of the cables was injured while being drawn through an iron pipe.

Not in accord with facts is another remark made by the speaker, that without any previous mechanical injury of the cable a current may pass between the lead mantle and the iron armor, if the surrounding ground is strongly saturated with chlorates. But this however is not possible, for the reason that, without a direct contact of iron and lead, a closed circuit cannot exist. Moreover, from the proctocol referring to the four defects found within the Berlin system of cables, it appears that the current thus created is only then strong enough to exert a decomposing action on the iron when iron and lead are entirely molten together. That a simple contact between the two metals is sufficient to effect this has, in no instance, been confirmed. During the negotiations with the Allgemeine Elektricitats-Gesellschaft regarding the extension of the Berlin cable system, it has indeed been suggested to embed the cables in clear sand. It is, however, erroneous to draw therefrom with the speaker a confirmation to his assertion that chemically unfavorable soil must be disastrous to asphalted cables protected by an iron armor. Without a severe mechanical injury the cables, even in bad street ground, remain perfectly sound, as experience has sufficiently shown. Should there be, however, an injury of this kind in a cable, the consequences will make themselves more felt in a soil impregnated with chlorates than in pure sand. For this reason it is desirable to embed cables in good soil, and the previously mentioned suggestion has been made in this spirit.

In reference to the experiments made by the Allgemeine Elektricitats-Gesellschaft with bare copper conductors mounted on insulators in conduits, I think it is quite useful to gather experience as to this way of arranging conductors, and it is not impossible that thus practical knowledge, available in some cases, may be gained. But at all events this method lacks universal practicability. Rarely, I dare say, the conditions will be so favorable as is the case in the Zimmer-Strasse, where a short straight stretch of street is free for the experiment. In cities with curved and narrow streets, where the available space is claimed for various other purposes, surely considerable difficulties may interfere with the execution of such plans. You would then be compelled to apply a mixed system, consisting partly of bare conductors in conduits and partly of cables. Such a pell-mell of different systems must, however, appear especially disadvantageous, since, not considering any other inconveniences, all uniformity in the arrangement and control would be lost thereby. In my opinion this will be done only if absolutely coercent reasons make it necessary.

To this must be added certain other drawbacks inherent to the system of bare conductors in conduits. If these, in reality, do not turn out so grave as to make it necessary to desist from the use of bare conductors, they are, at any rate, disadvantages which must not be overlooked in the selection between this system and the one hitherto used and found satisfactory. One such drawback lies, for instance, in the low insulation of the conductors from the earth. Thereby a loss of current may be occasioned, which, in case water enters the conduit (for instance in case of floods, breakage of pipes, etc.), will be of some consequence. Then the resistance of the insulation of the whole network, low in itself, will show continual and considerable variations, making it very difficult to obtain a correct idea of the condition of the network, and to discover and locate any existing faults.

A further consequence of the low insulation of this system from the earth will be that men not perfectly insulated from the earth, in touching bare parts of conductors laying or repairing them, will be exposed to electric shocks. In case of plants with 100 volts tension this would be of no great consequence, though it is not very agreeable. In case of plants with 200 volts tension (to which the three-wire system belongs), we have to face already a considerable inconvenience. Besides, there can be no doubt that we have not yet reached the end of the development with plants using only 200 volts. On the contrary, even now central stations are in progress of construction on the 400 volt system. Hence the existing tendency of increasing the tension must be taken into account and not be lost sight of, substituting a new system of conductors for one which meets the requirements of this tendency. Entirely out of the question appears to me the application of the system of conductors, as advocated by the speaker, for alternating current systems using high tension. Therefore, I may be permitted to say that this system may find application in some cases, but it will never possess that universal usefulness which constitutes one of the chief advantages of the iron-armored lead cables. They are, besides, the only underground conductors suitable to carry heavy currents, and which have stood the test to the present, have really done satisfactory work, and about which a great number of experiences have been gathered.

Permit me to make another remark. It was very gratifying to me to learn from the statements of the speaker that he substantially agrees with the lecturer in his opinion upon iron-armored lead cables and the experience gained with these cables, and that he likewise opposed the censuring judgment of Professor Forbes. Nevertheless, I cannot forbear to express my regret that the prejudicial and entirely unjustified verdict concerning lead cables, which claims to be based exclusively upon the experience gained in Berlin, has already found a widespread circulation, especially in Germany.

Undoubtedly, without cause great difficulties have been thrown thereby in the way of establishing electric central stations, and it will be no easy task to overcome the prejudice once established. I think that the statements made to-day by the speaker will do much to dissipate this distrust, and I beg leave to express my thanks to him for it.

Privy Chief Councilor of Government Bensen—We all certainly agree in this, that it is not only our right, but also our duty, to defend ourselves before the world against attacks coming from other nations and relating to the electro-technical department. Only with regard to the way of doing this, permit me to say that, unfortunately, we have to-day been unable to summon before our forum that gentleman from whom, Professor Forbes says, he has received his information, and this is, to a certain extent, important. In the first place, I am not aware whether Mr. Forbes speaks German, nor do I know whether Mr. Rathenau speaks English. So I do not know how the two gentlemen have made themselves understood. Certainly we cannot summarily attribute a "dolus" (evil intention) to such a highly distinguished colleague from the other side of the channel. So we are obliged to presume that an error in understanding has taken place. Perhaps a translation of the address of Privy Councilor Von Siemens will not make such an impression on the other side. It appears to me rather as an attack which, on its part, challenges again a retaliation; for it has not been possible to say, "the whole matter has been entirely misrepresented," but only single cases been ascertained, so as to show that within a few years a destruction has taken place. I think, if a milder form were chosen in referring to another distinguished society and a highly distinguished professor, either by somewhat extenuating the introduction of the address of Mr. Von Siemens, or by stating more plainly, that "an error in the communication made to him was allowed to slip in," Mr. Forbes would then take occasion to rectify what he said in England, and thus we would attain amicably our desired object. If it is impossible to modify a word once spoken, then I would feel called upon to move that the association pass a resolution authorizing this modification of the protocol, on the supposition that no dolus (evil intention) was here to take place against us, but that a mere error has been made. I, therefore, would like to know your opinion about either side of this question.

Honorary President Dr. Von Stephan—I do not believe that an intentional misstatement is involved—and this Privy Councilor Von Siemens also assumed—but only a misunderstanding between Mr. Rathenau and Mr. Forbes. Perhaps Mr. Von Siemens would enter into communication with the gentlemen in order to learn how the matter stands.

Privy Councilor of Government Dr. Werner von Siemens—I think I have quite positively expressed the hope in my address that a misunderstanding has taken place. I must say that I considered myself justified in answering with a certain severity, because the attack was made with such reckless severity. Mr. Forbes says among other things:

"I have been told, but I cannot believe it, that there is one company in London actually proposing to put such lead-covered cables without covering into iron pipes. Of course, every one knows they would soon be eaten into by galvanic action."

With this severity he expresses himself, having as support four or, as is said now, five faults which appeared here in the underground system, and which have been entirely remedied by the renewal of only one-fifth per cent. of the total length of cables of the system. This is indeed an undue severity of judgment, which must be rebutted likewise with some severity. The English are rather accustomed to exercise upon foreigners a somewhat sharp and harsh criticism, as if beyond the Channel no people are to be found who could do good work just as well. I don't think I am in a position to extenuate the words used. By the way, even in the very same society he already received a reply which expresses about the same that I have said here.

Hon. President Dr. Von Stephan—Would you have any objection if it was tried to learn from Mr. Rathenau what was communicated by him?

Dr. Werner von Siemens—I would like this very much.

Director O. Von Miller—Allow me to state that an authoritative declaration as to this cable affair could only have been given by Mr. Rathenau, and that in English language a misunderstanding may have had its origin in the declaration of Mr. Rathenau, in which he, perhaps, said that for three years we were extraordinarily well satisfied with the cable system, and that not until three years had passed disturbances began to appear. The judgment of different people as to the value of a cable system in which during one year five disturbances have occurred may be very different. We were induced by their occurrence to look out for another more durable system of conductors, particularly as with increasing age of the cables and continued extension of the system of conductors the faults and disturbances may increase very rapidly.

Privy Chief Councilor of Government Bensen—Permit me to observe that if Mr. Rathenau can be induced, before this report is printed, to communicate to Geheimrath Von Siemens precisely what he [Mr. Rathenau] said to Mr. Forbes, I would consider the matter settled.

Privy Councilor of Government Dr. Werner von Siemens—I am much in favor of such a statement. I expected these last four weeks that something of the kind would be done spontaneously, as all this time the publications made their way over the whole world. But this has not been done. What I have said is my conviction, and my conviction I express under all circumstances, and, therefore, I must beg you that my address, as I have delivered it—I have read it to you from notes so as not to say anything which I cannot be held accountable for—be printed without changes. If any explanations are added, they may extenuate it.

The discussion closed here.

OPTICAL TORQUE.*

By Prof. SILVANUS P. THOMPSON.

I.

SEVENTY-EIGHT years have elapsed since the first discovery, by Arago, of the remarkable chromatic effects produced by slices of quartz crystals upon light, previously polarized, which was caused to traverse them. These effects were shown one year later, by Biot, to be caused by a peculiar action of the quartz in rotating the plane of polarization; the amount of the rotation being different for lights of different colors.

Ever since then, the rotation of the plane of polarization of light has been a topic familiar to physicists. It has stimulated the devotee of research to an endless variety of experiments and suggestive speculations; it has lured on the mathematician to problems which tax his utmost skill; it has afforded to the lecturer an array of beautiful and striking illustrations. Here, in this place, made classical by the researches and expositions of Thomas Young, of Michael Faraday, and of William Spottiswoode, and last, but not least, by the labors of those eminent men whom we rejoice still to number among the living—here, I say, on this classic ground, the rotation of the plane of polarization of light is almost a household word, and its phenomena are among the most familiar. We know now that not only certain actual crystals, such as quartz, bromate of soda, and cinnabar, rotate the plane of polarization, but that many non-crystalline bodies—liquids, such as turpentine, oil of lemons, solutions of sugar and of various alkaloids, and even certain vapors, such as that of camphor—possess the same property.

In 1845, at the very culminating point of his unique career of research, Faraday opened a new field of inquiry, linking together for the first time the science of optics with that of magnetism, by his discovery that the rotation of the plane of polarization of light could be effected by the application of magnetic forces. This effect he observed first in his peculiar "heavy glass," when it lay in a powerful magnetic field. Subsequently he found other bodies to possess similar properties: some of these being magnetic liquids, such as solutions of iron, others being diamagnetic. Time will only permit me in passing to refer to the researches of Verdet, and those of Lord Rayleigh and of Mr. Gordon upon the numerical values of the magneto-optic rotation in these substances. H. Becquerel has extended them to gases, and has shown how the magnetism of the earth rotates the plane of polarization of the light, which, previously polarized by reflection from the aerial particles which give the sky its "blue," passes earthward through the oxygen of the air.

Other experimenters have dealt with the rotary effects (whether crystalline, molecular, or magnetic) in relation to lights of different colors, and have studied the dispersion which arises from the greater actual angle of optical torsion which is produced upon waves of short wave length (violet and blue) than that which is produced under the influence of equal rotary forces upon the waves of longer wave length (red and orange). It has also been demonstrated that the plane of polarization of waves of invisible light, whether those of the infra-red or those of the ultra-violet species, if they had been previously polarized, can be rotated just as can that of waves of visible light.

In 1877, Dr. Kerr, of Glasgow, discovered a point which Faraday had sought for, but fruitlessly, namely, that in the act of reflection at the pole or surface of a magnet there is a rotation of the plane of polarization of light. This discovery was completed in 1884 by Kundt, of Strassburg, by the further demonstration, also dimly foreseen by Faraday, that a magneto-optic rotation of the plane of polarization is caused by the passage of previously polarized light through a normally magnetized film of iron so thin as to be transparent.

Lastly, in this brief enumeration, we were shown a month ago, by Oliver Lodge, how the magnetic impulses generated by the rapid oscillatory discharges of the Leyden jar can produce corresponding rapid oscillatory rotation in the plane of polarization of the waves of previously polarized light.

You will not have failed to notice the cumbrous phrase which, whether in speaking of the purely optical effects (of quartz, or sugar, or turpentine), or in speaking of the magneto-optic effects of more recent discovery, I have employed to connote a very simple fact. You may have woundered that any lover of simple English speech should indulge in such sesquipedalian words.

Of course, at this period of the nineteenth century it is no longer open to debate that light consists of waves. The plane of polarization of the waves of light is the plane of polarization of the light itself. The rotation of the plane of polarization is the rotation of the polarized waves and therefore of the polarized light itself. Yet I must draw attention to the fact that in all the array of discoveries which I have enumerated, that which had been observed was the rotation—whether by crystalline, molecular, or magnetic means—not of natural light, but of light which had by some means been previously polarized. It was not known to Arago or to Biot, to Fresnel, to Faraday, nor even to Spottiswoode or to Maxwell, that natural unpolarized light could be rotated. They may have inferred so, but it was not in their time even demonstrable that a beam of circularly polarized light could be rotated upon itself in the same sense as that in which a beam of plane-polarized light could be rotated.

That light of any and every kind, however polarized or devoid of that which is called polarization, can be, and in fact is, rotated when it passes across a slice of quartz or along a magnetic field, is a wider generalization of more recent date, but one of the reality of

* A discourse delivered at the Royal Institution, May 17, 1889, by Prof. Silvanus P. Thompson.—*Nature.*

which I hope to convince you before the warning finger of the clock puts a period to my discourse.

In order the better to enable this audience to comprehend the ultimate significance of this discovery, I must claim the indulgence of those among them who are already familiar with the subject of the polarization of light, while I go back to the most simple elementary matters. Having illustrated the fundamental facts about the plane of polarization of light and its twisting, I shall then go on to methods of precisely measuring the amount of optical torsion produced by the various substances under various conditions. And

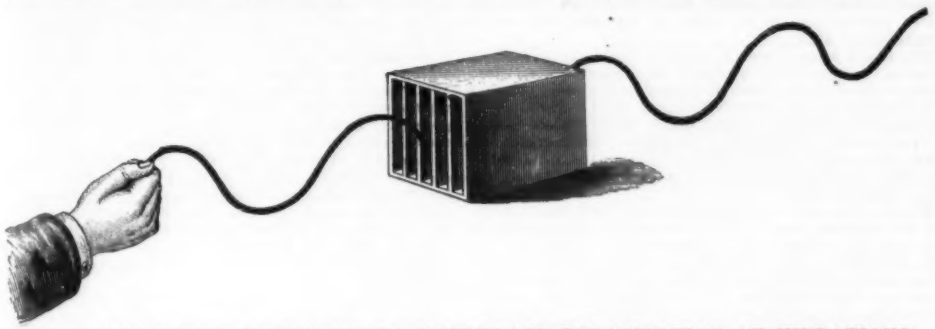


FIG. 1.—BOX WITH PARTITIONS TO ILLUSTRATE POLARIZATION OF VIBRATIONS.

after dealing with the magnetic as well as the crystalline and molecular methods of producing optical torsion in the case of light that has been previously polarized into a given plane, I shall be in a position to speak of the nature of the torque,* or twisting force, which in the several cases produces the torsion; and shall finally endeavor to indicate the scope of the researches by which it is now definitely ascertained that the very same optical forces which are capable of impressing a rotation upon light which has been artificially polarized into a definite plane are also capable of impressing a rotation upon natural, non-polarized light.

At the outset, to elucidate to any who may not comprehend the meaning of the term polarization as applied to wave motion, I will show a simple apparatus, constructed from my designs by Mr. Groves. In this there are two sets of movable beads, fixed upon stems which pass into a box containing a piece of mechanism actuated by means of a handle. These beads, when I turn the handle, oscillate to and fro in definite directions, and, by their successive motions, give rise

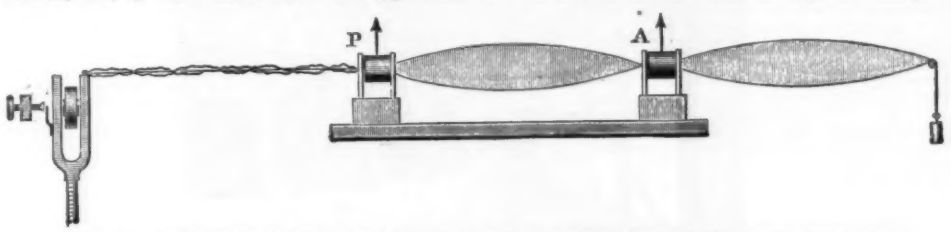


FIG. 2.—ACOUSTIC MODEL ILLUSTRATING POLARIZATION OF VIBRATIONS.
P, the polarizer; A, the analyzer.

to progressive waves. One set of beads, tinted red, executes movements in a plane inclined 45° to the right, another set, silvered, simultaneously executes movements at 45° to the left. There are therefore here two waves, the planes of polarization of their movements being at right angles to one another. Their velocity of march is equal; but in this model, as a matter of fact, their phases differ by one-quarter—that is to say, each successive wave of the one set is always a quarter of a wave length behind the corresponding wave of the other set. [Model exhibited.]

Now, in the case of waves of natural light from all ordinary sources—sun, stars, candles, gas flames, or electric light—the waves emitted are not found to be polarized. That is to say, their motions are not executed in any particular plane, nor even in any particular path of any kind; they appear to be absolutely heterogeneous at least so far as this, that no vibration of the millions of millions emitted in a second of time is followed by more (on the average) than about 50,000 vibrations of a similar sort, executed along a similar path, the plane of the polarization, if any, changing after the lapse of such an incredibly short time that

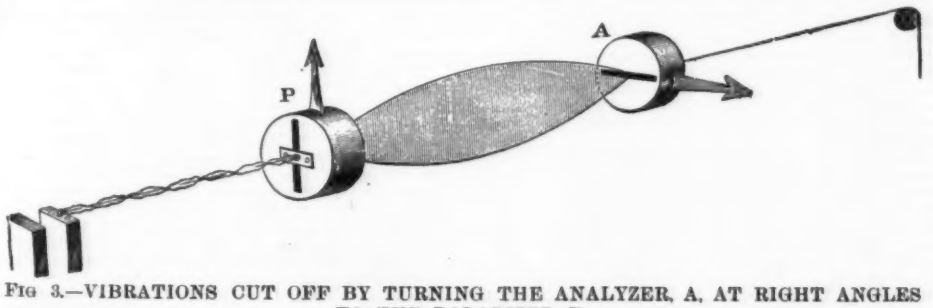


FIG 3.—VIBRATIONS CUT OFF BY TURNING THE ANALYZER, A, AT RIGHT ANGLES TO THE POLARIZER, P.

for most purposes the vibrations in different directions are as inextricably mixed as if they had all been simultaneously jumbled up. Since, then, natural light is non-polarized or miscellaneous, the production of polarized light must be brought about by the employment of polarizing apparatus or agents which will so

* The convenient term *torque* was first proposed by Prof. James Thomson, of Glasgow, for the older and more cumbrous phrase, "moment of couple," or "angular force." Its general acceptance by engineers justifies the extension of the term to optics. As a mechanical torque is that which produces or tends to produce mechanical torsion, so optical torque may be defined as that which produces or tends to produce optical torsion.

operate on or affect the mixed waves as to bring their vibrations into one direction, or, what amounts to the same thing, transmit the light while destroying or absorbing those parts of the vibrations which are executed *across* the desired line of vibration. So we have *polarizers* consisting of tourmaline slices; oblique bundles of thin glass plates, black glass reflectors, and Nicol prisms cut from calc spar. About the two latter I may be permitted a passing word presently. These objects polarize, *i. e.*, turn into one plane, the vibrations of light falling upon them. A rough mechanical illustration may here be permitted me. A long India-rubber cord is passed through the open ends of a box provided with vertical partitions. Fig. 1 shows the arrangement. These partitions confine the motion of the cord, and effectually polarize the vibrations which I now impart to the cord by shaking the end of it to and fro. If the partitions are vertical, the box polarizes into vertical vibrations only the miscellaneous vibrations which are sent to it. If rotated until its partitions are horizontal, it polarizes the vibrations into a horizontal position.

Let us now turn to the optical analogue of this experiment. The large Nicol prism which I introduce into the field of the electric light lantern polarizes the light, so that the vibrations are executed simply in an up and down direction. Your eye will not detect this, the motions being millions of times too rapid. To detect the direction, an analyzer is necessary. For this purpose a second apparatus of the same sort is used, for then, by crossing the positions of the two, the whole of the light is cut off: the second Nicol prism, if set so as to transmit only horizontal vibrations, cutting off the vertical vibrations that are sent through the first prism. So while the first prism serves as a polarizer, the second serves as an analyzer to detect by cutting them off when turned to the proper position, the direction of the polarization which had been previously impressed by the first prism.

Here I may illustrate the action of the analyzer for determining the plane of polarization of the vibrations, by the extinction which it produces when turned to the crossed position. For this purpose I have refined upon the box with partitions, using instead parallel plates of glass mounted in wooden cylinders, while for the cord swung by hand I am using Prof. Schwedoff's device, and am producing the vibrations in this silken cord by means of an electrically driven tuning fork (Fig. 2). At the first nodal point of the stretched cord a pair of parallel glass plates acts as a polarizer, the cord from that point vibrating in the plane thus imposed upon it. I can alter this plane at will by rotating the polarizer. This polarizer, P, consisting of a pair of glass plates, is mounted in a cylindrical mount, and is provided with an arrow to indicate their direction. If now at any subsequent node I introduce a second such device, it will act as an analyzer, A. This excellent suggestion is due to M. Mace de Lepinay. In Fig. 2 the polarizer and analyzer are parallel. You see (Fig. 3) how the vibration is extinguished when the positions of analyzer and polarizer are crossed. Half a degree of error in the position of the analyzer produces something less than perfect extinction of the vibrations. Hence, it is possible, by this analyzer, to determine the plane of the vibrations to the accuracy of half a degree. I should say that the whole of this model has been constructed by my assistant, Mr. Eustace Thomas.

Now let me show you the optical effect which corresponds to this. Placing a second Nicol prism as analyzer in the path of the polarized waves, I turn it to the position where it cuts off the polarized light. The "*dark field*" so produced by the crossed Nicol prisms corresponds to the motionless cord beyond the crossed analyzer of the acoustic apparatus.

Returning for a moment to two well-known forms of polarizing apparatus, viz., the black glass reflector and the Nicol prism, I may be permitted to refer to some recent attempts to improve upon these devices.

The Nicol prism, as is well known, consists of a rhomb of Iceland spar cut into two pieces, which are reunited by a film of Canada balsam. As originally devised, it had oblique end faces (Fig. 4) and a comparatively

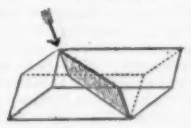


FIG. 4.—NICOL PRISM—ORIGINAL FORM.

narrow angle (19°) of aperture. These may be noticed in the small example which I here exhibit, which is an original constructed by William Nicol himself. It also has the disadvantage of giving a field in which the directions of the planes of polarization are not strictly parallel to one another throughout its whole extent. Consequently there is never complete extinction of light all over the field at one time. Hartnack and others have attempted to remedy this by giving the prism a different form and using other materials than Canada balsam. I have from time to time made many attempts to improve upon the original construction. First, I have made the end faces principal planes of section (Fig. 5); secondly, I have made the axis of vis-

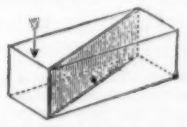


FIG. 5.—S. P. THOMPSON'S MODIFICATION OF THE NICOL PRISM.

ion cross the crystallographic axis at right angles, so getting a flatter field, a shorter length, a wider angle, and less loss of light by reflection. Mr. Ahrens, the prism cutter, on whose able assistance I have relied during the last six or seven years in cutting these prisms, has aided me with his ingenuity in devising a method of cutting up the spar so as to give these advantages with a minimum waste of material. He has further devised a method of putting a polarizing prism together in three instead of two pieces—illustrated in the diagram (Fig. 6), which gives a still wider angle.

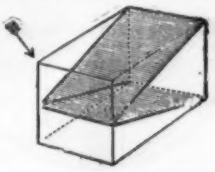


FIG. 6.—AHRENS' TRIPLE PRISM.

The prism which I shall use as analyzer in the next experiments is one of these forms.

Unfortunately, at present there is a spar famine, pieces of Iceland spar of a size and purity suitable for the making of large polarizers such as that I employ being not now procurable at any price. To avoid the excessive cost of large Nicols, I have lately got Mr. Ahrens to construct for me a large reflection polarizer, on the plane of Delezenne, but modified by Mr. Ahrens in detail. In this prism the light is first turned to the proper polarizing angle by a large total reflection prism of glass, and then reflected back, parallel to its original path, by impinging upon a mirror of black glass covered by a single sheet of the thinnest patent plate glass to increase the intensity of the light. This form of polarizer, depicted in Fig. 7, is quite equal for projection purposes to a Nicol prism of equal aperture, and is much less costly. This one has 2½ inches clear aperture.

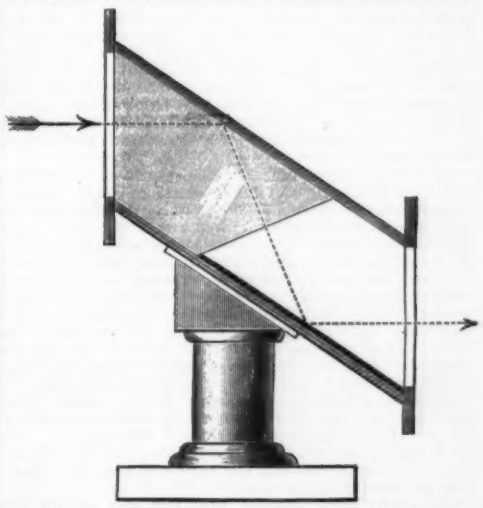


FIG. 7.—AHRENS' REFLECTING POLARIZER.

Having so far reviewed the apparatus for polarizing and analyzing, I will return to the apparatus set with its prisms crossed, so that the analyzer completely extinguishes the polarized light emitted from the polarizer.

If in the space between polarizer and analyzer anything be introduced which can either resolve obliquely the polarized vibrations or twist them bodily round, then there will not be complete extinction; the amount of light passing the analyzer depending in the one case on the obliquity of the resolution, in the other upon the degree to which the vibrations are twisted or rotated upon themselves.

The effect of oblique resolution I may illustrate by introducing a slice of tourmaline between the crossed Nicols, and rotating it till it stands at 45°; or, in the acoustic model, by introducing an oblique pair of guide pins.

The other case, namely, that of producing a bodily twist of the vibrations, rotating the plane of polarization around the path of the wave, is not so easily illustrated by the model. But it is optically perfectly simple; all that is requisite is to introduce between the crossed Nicols a thin slice of that crystal—namely, quartz—in which this effect of rotating the plane of polarization was first observed.

I take a clear plate of quartz, just one millimeter in thickness, and interpose it between the crossed Nicol prisms. You will note how the introduction of this plate of quartz brings *some* light into view.

Suppose we now turn the analyzer to try and obtain extinction; we get tinting. If we put in a colored glass so as to work with one kind of light only, we shall get extinction at a particular angle. The table of data to which I invite your attention states this amount for

Optical Torsion produced by Plate of Quartz.

	1 millimeter. Deg.	3·75 millimeters. Deg.
Red	19	71·2
Orange	21·5	80 6
Yellow	24	90
Green	29	108 7
Peacock	31	116·2
Blue	35·5	133 1
Violet	42·8	161

the different colors. If we use a piece of quartz so thick that it rotates any particular tint just 90°, that tint will be cut off by the crossed analyzer, and all others will, in greater or less proportion, be transmitted, so that the resulting tint will be complementary to that cut off. For example, a slice just so thick as to twist yellow waves round 90° must be 3·75 millimeters thick. (I may remark, for the benefit of those who think it easier to express this exact thickness in fractions of a British inch, that the quartz which rotates yellow light 90° must have a thickness equal to one-eighth, plus three-sixteenths of an eighth, plus one

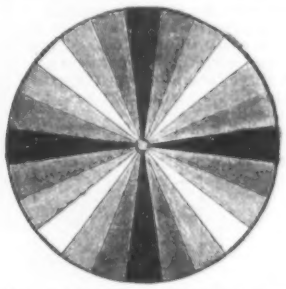


FIG. 8.—MICA DISK OF TWENTY-FOUR RAYS, SHOWING BLACK CROSS IN THE DARK FIELD.

sixty-fourth of an eighth of an inch.) When such a quartz is placed between the crossed Nicols, the light shown is yellow, but if placed between parallel Nicols (*i. e.*, in the bright field), it shows a rich purplish-violet color, the complementary of the yellow. This particular tint Biot found to be excessively sensitive, the smallest inaccuracy in adjustment between the prisms at once producing a change, the color appearing too red or too blue, according to the direction in which the analyzer has been turned out of exact adjustment. This tint is accordingly known as the "transition tint" or "sensitive tint," its accurate definition being due to the fact that the human eye is more sensitive to the presence or absence of the complementary yellow than to any other tint in the whole spectrum. If we take, however, a quartz plate twice as thick as this—namely, 7½ millimeters thick—this will give the yellow light a torsion of 180°. Hence this gives the purple transition tint in the dark field, and is yellow in the bright field. A quartz plate 11¼ millimeters thick gives again a transition tint in the bright field. I shall recur presently to the question of the transition tints of the several orders.

One of the familiar facts in this subject is that there are two kinds of quartz crystals, optically alike in every other respect, differing only in this, that one kind produces a right-handed twist, the other kind a left-handed twist. All the pieces of quartz I have so far employed are right-handed specimens. I now introduce two small slices of crystal, each 3¾ millimeters thick, giving the yellow tint when the Nicols are exactly crossed, but you will notice that when we are using the right-handed crystal, the tint grows reddish as the analyzer is turned toward the left, and greenish when the analyzer is turned toward the right; whereas, when I substitute the left-handed slice, the tint grows greenish as the analyzer is turned toward the left, and reddish when it is turned toward the right. If the analyzer is turned through an exact right-angle, we get an extinction of the yellow light, the remaining blue and red rays combining to give us the purple transition tint.

You will have noticed that the way in which we have (approximately) measured the angle of rotation has been first to set the analyzer to extinction, then to introduce the substance which has the property of rotating the beam, then to turn the analyzer again to extinction, and read off its angle. For, of course, the angle through which the analyzer is turned measures the angle through which the plane of polarization has been turned.

It is possible, however, to show in the lantern something like a more obvious rotation of the light by introducing between the Nicols a crystal star, built up of radial pieces of mica, twenty-four in number (Fig. 8). You see in the bright field a white cross with black sectors at 45°. Or, in the dark field we have a black cross with vertical and horizontal arms, the sectors next to those that are black seeming dusky. If now I put in a quartz plate between the star and the analyzer you see the cross shift round, and it shows colors, because the blue rays are twisted round more than the green, the green than the yellow, the yellow than the red. Repeating the experiment with the 3·75 millimeter quartz which turns yellow waves round just 90°, we get this gorgeous radiation of colors, and our black cross is turned into a yellow one. With the 7·5 millimeter quartz, the black cross is replaced by one of "transition" tint.

The black crosses seen in certain sections of natural crystals, sphæroliths, sections of stalactites, crystallizations of salicine and of Epsom salts, may also be used instead of the 24-rayed star of mica. But best of all I find to be the beautiful black cross which is seen by polarized light in the prepared crystalline lens taken from the eye of a fish. You notice how, when the fish lens is projected and the quartz introduced, the cross turns round.

This is, however, a rough and ready way of displaying the rotation, and it is of vast practical importance that precise methods of measuring the angle of rotation should be available—of vast importance, because in several large industries this optical method is applied as a species of handy analysis. I have named a solution of sugar as being an "active" substance. In the industry of sugar refining, as in that of brewing, the strength of sugar in the liquids is directly measured by measuring its optical effect. Consequently there has been developed a special instrument, the *polarimeter*, for this express purpose.

I have here examples of several practical forms of polarimeters: there are diagrams of several more upon the walls.

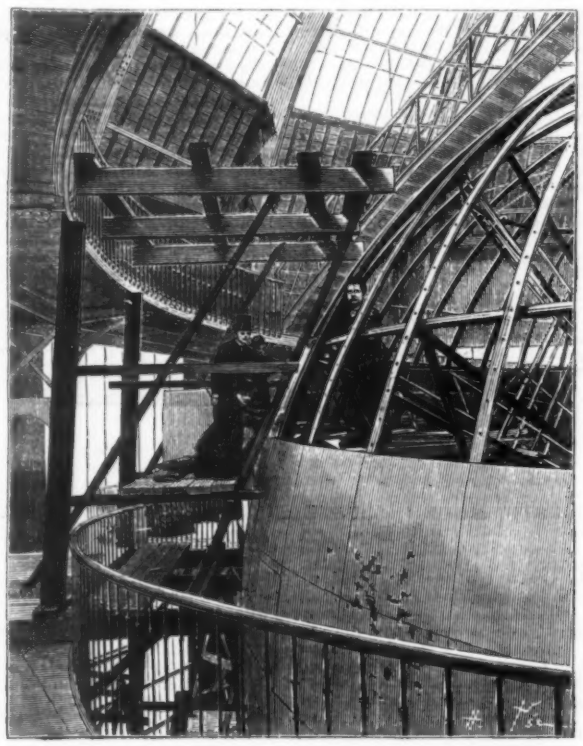


FIG. 1.—CONSTRUCTION OF THE TERRESTRIAL GLOBE.

The problem of finding the best polarimeter naturally leads to the inquiry, What special means are there for making the observation of the angle more precise than by merely observing the extinction of the light, its restoration when the active substance is interposed, and the subsequent renewal of extinction when the analyzing prism is turned?

Biot considered that much greater accuracy could be attained by watching for the restoration of the sensitive tint than by watching for the mere restoration of extinction of the light. Accordingly, we will use the plate of quartz 7·5 millimeters thick, giving the purple tint, to enable us to measure the rotation produced by the tube of sugar solution which is now inserted in the beam of polarized light. You notice how the tint has changed. But I have only to turn the analyzer to an amount equal to that to which the light has been twisted by the sugar, and again I obtain the sensitive transition tint.

The eye is not always, however, alive to minute changes of color in a single colored patch; it much more readily distinguishes a minute difference between two tints when both are present at once. Hence Soleil devised the well known biquartz arrangement, consisting of two pieces of crystal, equal in thickness but possessing opposite rotations. You will notice how the slightest inaccuracy in placing the analyzer causes the two halves of the field to differ in tint. This is especially marked when the tint chosen is the transition purple.

(To be continued.)

THE TERRESTRIAL GLOBE AT THE PARIS EXPOSITION.

IT was but a short time ago, if we consider the long duration of the ages through which the history of humanity has passed, that scarcely anything was accurately known concerning our globe, its sphericity, and the relative areas of the continents and seas. We are filled with astonishment when we think that the whole new world was still to be discovered at the moment when Columbus suspected the existence of it, that is to say, about four hundred years ago. Geography is an absolutely recent science, and it is within but a very few years that its importance has been understood. The efforts of those who have rendered themselves popularizers of it cannot be too much encouraged, and we unreservedly applaud the grand project that Messrs. Villard & Cotard have carried out on the Champ de Mars in their construction of their terrestrial globe to the millionth—an immense map world full of instruction.

Messrs. Villard & Cotard have recently published an excellent description of their work, and from this we borrow the details that we shall give on the subject.

Maps projected upon plane surfaces destroy the idea of the earth's rotundity, more or less distort the extreme contours, and give no idea of the respective positions of the continents. Moreover, the diversity of their scales renders comparison between the areas represented very difficult. As for globes, they are generally much too small to permit of establishing a useful relation with the usual maps.

It would, therefore, be very interesting to construct a globe whose dimensions should be sufficient to offer all the advantages of maps drawn to a common scale, and, at the same time, to give, if possible, a more evident relation with the real size of the earth.

Such was the thought that led Messrs. Villard & Cotard to the construction of a globe on a scale of a millionth.

This geographical work presented great difficulties. It was a question, in fact, of constructing a globe 42 feet in diameter, of figuring upon it all the details of the earth's surface, of protecting it under a vast dome, and of rendering all the parts easily visible. The globe is formed of an iron frame consisting chiefly of a series of meridians connected with a central core. This latter is carried by a pivot, which rests upon an iron framework. The meridians are faced with wood, and upon the latter is fixed the superficial covering of the globe. This covering consists of sheets of cardboard manufactured by hand in a spherical form and coated with a specially hardened plaster. Fig. 1 shows the manner in which the cardboard was applied to the frame. The total surface is divided into 40 elliptical pieces of 9 degrees or 10 grades each, the width of which is exactly 3·28 feet at the equator. There are, in all, 600 pieces, having various dimensions. The painting was done directly upon these pieces before they were put in place, so as to permit of the future dismounting and carriage of the globe.

The building that contains the globe consists of a metallic framework, forming a dome. It is lighted from above and through large windows at the sides. The visitor enters either through a staircase or an elevator, both of which take him to a platform or a bridge in the upper story, whence he can inspect the polar part as well as the temperate regions of the hemisphere. He afterward descends a spiral footway that permits him to see in succession all the regions of the globe as far as to the South Pole. Beneath, in a pit, is located the support of the globe, along with the apparatus by which it is set in motion (Fig. 2).

This globe, which is of great interest to scientists, is especially a work of scientific popularization, and, at the same time, a philosophical tentative toward a material representation of our planet.

Such a work, which, in 1889, will characterize our knowledge of geography, could scarcely have been attempted sooner. It is within but a few years that it has been possible to figure the mountains and rivers of the globe with accuracy, and such information still remains relatively obscure, especially as regards the great African continent, whose geography is being constantly modified and improved, and to such a point, too, that the projectors of the globe under consideration have had to alter this continent twice in order to reproduce upon it the modifications of the most recent maps. The same is the case with the central regions of South America and of the immense Chinese empire, which alone contains almost a third of the population of the globe, and the geographical outlines of which are as yet but partially known to us.

A terrestrial sphere of such dimensions cannot fail, from every point of view, to afford most instructive teaching. Our metric unit is the forty-thousandth of the meridian; this sphere is 40 meters (131 feet) in circumference, and a kilometer (0·6 inch) is therefore represented by one millimeter (0·4 inch). This globe, through its aspect alone, gives an impression of grandeur, and, at the same time, makes a person feel how small he is as compared with the earth. From such a contrast springs a possible appreciation of real dimensions, because the notion of a million is accessible to the mind.

On this scale the idea of the real size of the earth is no longer an absolutely pure abstraction, at least for our imagination, if not for our eyes. The Champ de Mars globe is, with respect to the earth, as a grain of the finest sand would be with respect to the globe. On this scale of a millionth, the geographical details can be sufficiently indicated, and some of them appear in their true measurement. For the first time upon a globe is seen the place really occupied by certain spaces of known dimensions, such as those of some of the large cities. Paris, for example, occupies nearly 0·155 of a square inch. Hence at once a ratio clearly established between this 0·155 of a square inch, which is Paris, and the surface of the globe, which is the earth, and through such ratio a clearer perception of the comparative dimensions of the various countries, continents, and seas. It is on this same principle of proportionality that the projectors of the globe thought it not well to represent in projection the heights of the mountains (the highest of which would have been but a few fractions of an inch), and that they confined themselves to figuring them by painting. From this standpoint, equally, this great sphere will furnish a valuable instrument of instruction upon the constitution of the earth, the relative thinness of its crust, and its atmosphere, the respirable limits of which, reached by aeronauts, stop, too, at a few fractions of an inch from the surface.

The depths of the sea, too, are indicated only by tints of varying depth; but these various data are figured upon a drawing exhibited in the building, representing on the same scale of a millionth, that is to say, with the same curve as the globe, the heights of the largest mountains, the probable height of the atmosphere, and the thickness of the solid crust as far as to the mass in fusion, which, at a depth of 40 miles, has probably a temperature of 2,000°.

In order to facilitate the reading of the maps, the globe is mounted with its axis vertical, and is capable of revolving upon the pivot that supports it. If we imagine that it has a rotary motion equal to the daily motion of the earth, at its equator, any one point of its surface will move at the rate of 0·2 of an inch per second. Such a velocity would be scarcely visible; but, on prolonging, in imagination, its radius to a million times its length, we shall understand how the same point really passes over 0·3 of a mile in the same time.

Finally, this globe gives a clearer idea of the extent of our solar system through the indication of the proportional distances and dimensions of the sun and planets. On this same scale of a millionth, the moon would be 11½ feet in diameter, and 1,260 feet distant; the sun would be nearly 4,600 feet in diameter, and about 90 miles distant. The diameter of Jupiter would be half, and that of Saturn a little more than a third of the height of the Eiffel tower. Venus would be of the same size as the globe; Mars would be half smaller. The sun, placed in the same center as the globe, would of course surround the moon in its mass, and its circumference would extend to a radius of 2,300 feet.

These examples alone suffice to show the advantage that can be derived from this sphere in giving an idea of proportions which, otherwise, remain entirely inaccessible to the mind.

From a geographical point of view, this globe furnishes valuable data as to the position, form, and comparative extents of the various countries, and as to the immensity of the seas. One is struck to see Europe, which has held so great a place in history in recent centuries and in the universal movement, as if lost

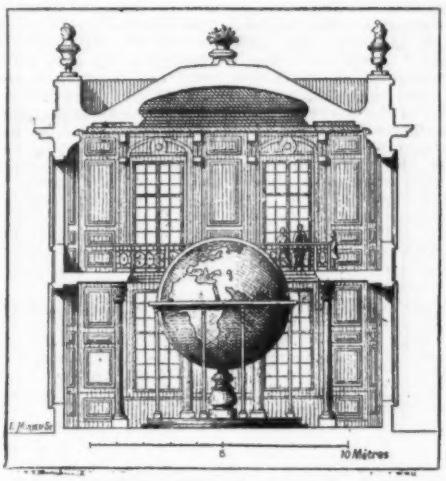


FIG. 3.—THE CHATEAU DE MARLY GLOBE.

near the pole, and so small with respect to great and scarcely explored continents. We perceive the railways multiplying their lines in the most prosperous countries and extending their great international ways through countries scarcely as yet acquired to civilization; the lines of the great navigation companies connecting, almost at the same speed, the continents by sea; and, finally, the telegraph lines uniting the most distant points of the globe through their instantaneous communications.

This general view, as Messrs. Villard & Cotard rightly say, gives the measure of the immense work accomplished during this century, which is made illustrious by the most astonishing conquests of science, and at the same time shows the extent of the countries which still await the benefits of civilization. Nothing could, to so high a degree, promote the ardor of discoveries and of bold enterprises.

A promenade around the globe is most instructive and is calculated to open the mind to wholesome meditation. When the summit of the structure is reached, we perceive the vast polar regions which as yet defy the audacity of explorers, and amid which so many brave men have succumbed in the name of science. As we gradually descend the spiral footway, we observe the continents; then we are seized with astonishment on traversing the hemisphere that comprises the Pacific, the immensity of which is indeed startling. The reader will recall that phrase of Michelet's, who in speaking of the sea said: "Upon the globe, water is the generality, earth the exception."

In passing before Australia and before Africa, we obtain an idea of the magnitude of the domains that it still remains to open to mankind, and, beneath the sphere, the austral regions give you the same feeling as does the view of the boreal ones.

The Champ de Mars globe is certainly one of the most remarkable monuments of geography, and leaves far behind it all former attempts in this line. One may judge of this from the reproduction that we here give (Fig. 3) of the globe of the Chateau de Marly, which was the admiration of the geographers of the age of Louis XIV. This globe was about ten feet in diameter. The pavilion that contained it no longer exists, but the globe itself is at present in the National Library at Paris.—*La Nature.*

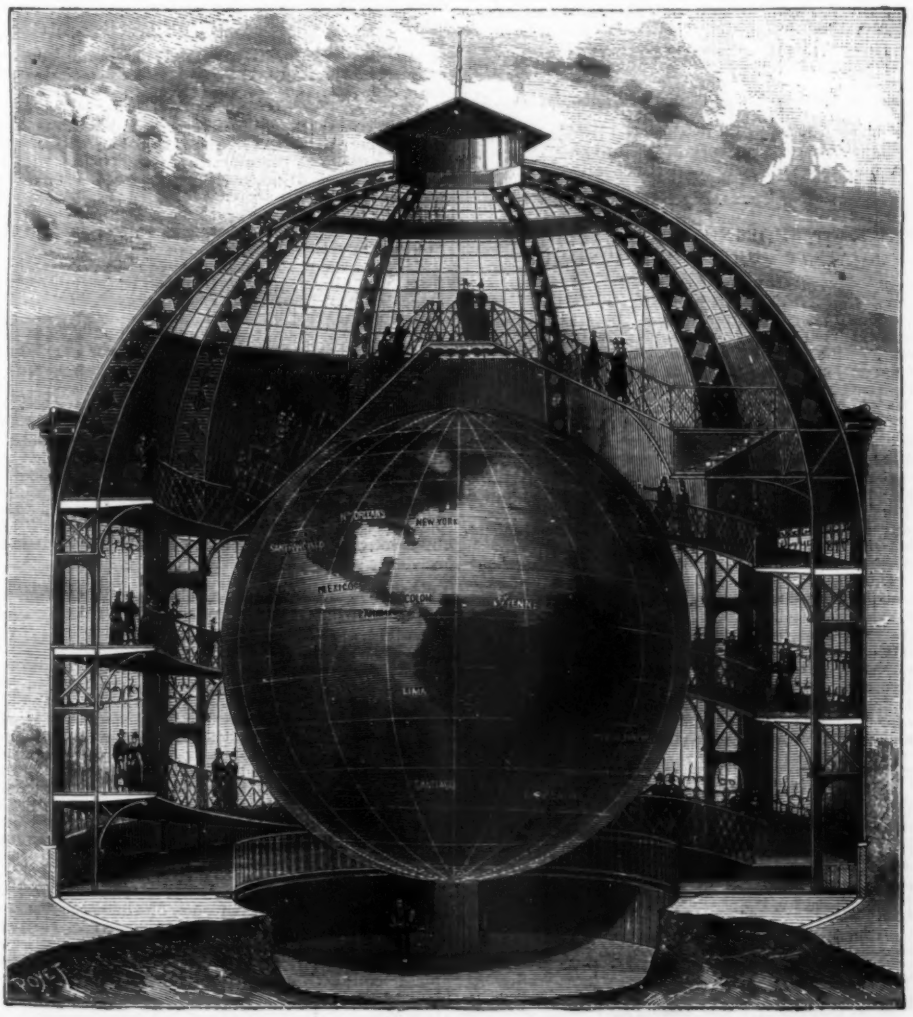


FIG. 2.—GENERAL VIEW OF THE TERRESTRIAL GLOBE AT THE PARIS EXHIBITION.

NOTE ON THE EFFECTS PRODUCED ON MAN BY SUBCUTANEOUS INJECTIONS OF A LIQUID OBTAINED FROM THE TESTICLES OF ANIMALS.

By Dr. BROWN-SEQUARD, F.R.S., Etc.

ON the 1st of June last I made, at the Societe de Biologie, of Paris, a communication on the above subject, which was published in the *Comptes Rendus* of that Society on June 21 (No. 24). I will give here a summary of the facts and views contained in that paper and in two subsequent ones, adding to them some new points.

There is no need of describing at length the great effects produced on the organization of man by castration, when it is made before the adult age. It is particularly well known that eunuchs are characterized by their general debility and their lack of intellectual and physical activity. There is no medical man who does not know also how much the mind and body of men (especially before the spermatic glands have acquired their full power, or when that power is declining in consequence of advanced age) are affected by sexual abuse or by masturbation. Besides, it is well known that seminal losses, arising from any cause, produce a mental and physical debility which is in proportion to their frequency. These facts and many others have led to the generally admitted view that in the seminal fluid, as secreted by the testicles, a substance or several substances exist which, entering the blood by resorption, have a most essential use in giving strength to the nervous system and to other parts. But if what may be called spermatic anæmia leads to that conclusion, the opposite state, which can be named spermatic plethora, gives as strong a testimony in favor of that conclusion. It is known that well organized men, especially from twenty to thirty-five years of age, who remain absolutely free from sexual intercourse or any other causes of expenditure of seminal fluid, are in a state of excitement, giving them a great, although abnormal, physical and mental activity. These two series of facts contribute to show what great dynamogenic power is possessed by some substance or substances which our blood owes to the testicles.

For a great many years I have believed that the weakness of old men depended on two causes—a natural series of organic changes and the gradually diminishing action of the spermatic glands. In 1869, in a course of lectures at the Paris Faculty of Medicine, discussing the influence possessed by several glands upon the nervous centers, I put forward the idea that if it were possible without danger to inject semen into the blood of old men, we should probably obtain manifestations of increased activity as regards the mental and the various physical powers. Led by this view, I made various experiments on animals at Nahant, near Boston (United States), in 1875. In some of those experiments, made on a dozen male dogs, I tried vainly, except in one case, to engraft certain parts or the whole body of guinea pigs. The success obtained in the exceptional case served to give me great hopes that by a less difficult process I should some day reach my aim. This I have now done. At the end of last year I made on two old male rabbits experiments which were repeated since on several others, with results leaving no doubt as regards both the innocuity* of the process used and the good effects produced in all those animals. This having been ascertained, I resolved to make experiments on myself, which I thought would be far more decisive on man than on animals. The event has proved the correctness of that idea.

Leaving aside and for future researches, the questions relating to the substance or substances which, being formed by the testicles, give power to the nervous centers and other parts, I have made use, in subcutaneous injections, of a liquid containing a small quantity of water mixed with the three following parts: First, blood of the testicular veins;† secondly, semen; thirdly, juice extracted from a testicle crushed immediately after it had been taken from a dog or a guinea pig. Wishing in all the injections made on myself to obtain the maximum of effects, I have employed as little water as I could. To the three kinds of substances I have just named, I added distilled water in a quantity which never exceeded three or four times their volume. The crushing was always done after the addition of water. When filtered through a paper filter, the liquid was of a reddish hue and rather opaque, while it was almost perfectly clear and transparent when Pasteur's filter was employed. For each injection I have used nearly one cubic centimeter of the filtered liquid. The animals employed were a strong and, according to appearances, perfectly

* This innocuity was also proved on a very old dog by twenty subcutaneous injections of a fluid similar to that I intended to employ on myself. No apparent harm resulted from these trials, which were made by my assistant, Dr. D'Arsonval.

† For reasons I have given in many lectures in 1869 and since, I consider the spermatic as also the principal glands (kidneys, liver, etc.) as endowed, besides their secretory power, with an influence over the composition of blood, such as is possessed by the spleen, the thyroid, etc. Led by that view, I have already made some trials with the blood returning from the testicles. But what I have seen is not sufficiently decisive to be mentioned here.

healthy dog (from two to three years old) and a number of very young or adult guinea pigs. The experiments so far do not allow of a positive conclusion as regards the relative power of the liquid obtained from a dog and that drawn from guinea pigs. All I can assert is that the two kinds of animals have given a liquid endowed with very great power. I have hitherto made ten subcutaneous injections of such a liquid—two in my left arm, all the others in my lower limbs—from May 15 to June 4 last. The first five injections were made on three succeeding days with a liquid obtained from a dog. In all subsequent injections, made on May 24, 29, and 30, and June 4, the liquid used came from guinea pigs. When I employed liquids having passed through Pasteur's filter, the pains and other bad effects were somewhat less than when a paper filter was used.

Coming now to the favorable effects of these injections, I beg to be excused for speaking so much as I shall do of my own person. I hope that it will easily be understood that, if my demonstration has any value—I will even say any significance—it is owing to the details concerning the state of my health, strength, and habits previously to my experiments, and to the effects they have produced.

I am seventy-two years old. My general strength, which has been considerable, has notably and gradually diminished during the last ten or twelve years. Before May 15 last, I was so weak that I was always compelled to sit down after half an hour's work in the laboratory. Even when I remained seated all the time, or almost all the time, in the laboratory, I used to come out of it quite exhausted after three or four hours' experimental labor, and sometimes after only two hours. For many years, on returning home in a carriage by six o'clock after several hours passed in the laboratory, I was so extremely tired that I invariably had to go to bed after having hastily taken a very small amount of food. Very frequently the exhaustion was so great that, although extremely sleepy, I could not for hours go to sleep, and I only slept very little, waking up exceedingly tired. *

The day after the first subcutaneous injection, and still more after the two succeeding ones, a radical change took place in me, and I had ample reason to say and to write that I had regained at least all the strength I possessed a good many years ago. Considerable laboratory work hardly tired me. To the great astonishment of my two principal assistants, Drs. D'Arsonval and Henocque, and other persons, I was able to make experiments for several hours while standing up, feeling no need whatever to sit down. Still more: one day (the 23d of May), after three hours and a quarter of hard experimental labor in the standing attitude, I went home so little tired that after dinner I was able to work and to write for an hour and a half a part of a paper on a difficult subject. For more than twenty years I had never been able to do as much.† From a natural impetuosity, and also to avoid losing time, I had, till I was sixty years old, the habit of ascending and descending stairs so rapidly that my movements were rather those of running than of walking. This had gradually changed, and I had come to move slowly up and down stairs, having to hold the banister in difficult staircases. After the second injection I found that I had fully regained my old powers, and returned to my previous habits in that respect.

My limbs, tested with a dynamometer, for a week before my trial and during the month following the first injection, showed a decided gain of strength. The average number of kilogrammes moved by the flexors of the right forearm before the first injection was about 34½ (from 31 to 37), and after that injection 41 (from 39 to 44), the gain being from 6 to 7 kilogrammes. In that respect the forearm flexors re-acquired, in a great measure, the strength they had when I was living in London (more than twenty-six years ago). The average number of kilogrammes moved by those muscles in London in 1863‡ was 43 (40 to 46 kilogrammes).

I have measured comparatively, before and after the first injection, the jet of urine in similar circumstances—*i. e.*, after a meal in which I had taken food and drink of the same kind in similar quantity. The average length of the jet during the ten days that preceded the first injection was inferior by at least one quarter of what it came to be during the twenty following days. It is therefore quite evident that the power of the spinal cord over the bladder was considerably increased.

One of the most troublesome miseries of advanced life consists in the diminution of the power of defecation. To avoid repeating the details I have elsewhere given in that respect, I will simply say that after the first days of my experiments I have had a greater improvement with regard to the expulsion of fecal matters than in any other function. In fact, a radical change took place, and even on days of great constipation the power I long ago possessed had returned.

With regard to the facility of intellectual labor, which had diminished within the last few years, a return to my previous ordinary condition became quite manifest during and after the first two or three days of my experiments.

It is evident from these facts and some others that all the functions depending on the power of action of the nervous centers, and especially of the spinal cord, were notably and rapidly improved by the injections I have used. The last of these injections was made on June 5th, about five weeks and a half ago. I ceased making use of them for the purpose of ascertaining how long their good effects would last. For four weeks no marked change occurred, but gradually, although rapidly, from the 3d of this month (July) I have witnessed almost a complete return of the state of weakness which existed before the first injection. This loss of strength is an excellent counter proof as regards the demonstration of the influence exerted on me by the subcutaneous injections of a spermatic fluid.

My first communication to the Paris Biological Society was made with the wish that other medical men advanced in life would make on themselves experiments similar to mine, so as to ascertain, as I then stated, if the effects I had observed depended or not on any special idiosyncrasy or on a kind of auto-suggestion without hypnotization, due to the conviction which I had before experimenting that I should surely obtain a great part at least of these effects. This last supposition found some ground in many of the facts contained in the valuable and learned work of Dr. Hack Tuke on the "Influence of the Mind over the Body." Ready as I was to make on my own person experiments which, if they were not dangerous, were at least exceedingly painful, I refused absolutely to yield to the wishes of many people anxious to obtain the effects I had observed on myself. But, without asking my advice, Dr. Variot, a physician who believed that the subcutaneous injections of considerably diluted spermatic fluid * could do no harm, has made a trial of that method on three old men—one fifty-four, another fifty-six, and the third sixty-eight years old.† On each of them the effects have been found to be very nearly the same as those I have obtained on myself. Dr. Variot made use of the testicles of rabbits and guinea pigs.

These facts clearly show that it was not to a peculiar idiosyncrasy of mine that the effects I have pointed out were due. As regards the explanation of those effects by an auto-suggestion, it is hardly possible to accept it in the case of the patients treated by Dr. Variot. They had no idea of what was being done; they knew nothing of my experiments, and were only told that they were receiving *fortifying* injections. To find out if this qualification had anything to do with the effects produced, Dr. Variot, since the publication of his paper, has employed similar words of encouragement, while making subcutaneous injections of pure water on two other patients, who obtained thereby no strengthening effect whatever.‡

I believe that, after the results of Dr. Variot's trials, it is hardly possible to explain the effects I have observed on myself otherwise than by admitting that the liquid injected possesses the power of increasing the strength of many parts of the human organism. I need hardly say that those effects cannot have been due to structural changes, and that they resulted only from nutritive modifications, perhaps in a very great measure from purely dynamical influences exerted by some of the principles contained in the injected fluid.

I have at present no fact to mention which might serve to solve the question whether it would be possible or not to change structurally muscles, nerves, and the nervous centers by making during a good many months frequent injections of the fluid I have used. As I stated at the Paris Biological Society, I have always feared, and I still fear, that the special nutritive actions which bring on certain changes in man and animals, from the primitive embryonal state till death by old age, are absolutely fatal and irreversible. But in the same way that we see muscles which have from disease undergone considera ble structural alterations regain sometimes their normal organization, we may, I believe, see also some structural changes not essentially allied with old age, although accompanying it, disappear to such a degree as to allow tissues to recover the power they possessed at a much less advanced age.

Whatever may be thought of these speculations, the results I have obtained by experiments on myself and those which have been observed by Dr. Variot on three old men show that this important subject should be further investigated experimentally.§—*London Lancet.*

* I ought to say that, notwithstanding that dark picture, my general health is and has been almost always good, and that I had very little to complain of, excepting mercyism and muscular rheumatism.

† My friends know that, owing to certain circumstances and certain habits, I have for thirty or forty years gone to bed very early and done my writing work in the morning, beginning it generally between three and four o'clock. For a great many years I had lost all power of doing any serious mental work after dinner. Since my first subcutaneous injections I have very frequently been able to do such work for two, three, and one evening for nearly four hours.

‡ I have a record of the strength of my forearm, begun in March, 1860, when I first established myself in London. From that time to 1862 I occasionally moved as much as 50 kilogrammes. During the last three years the maximum moved was 36 kilogrammes. This year, previously to the first injection, the maximum was 37 kilogrammes. Since the injection it has been 44.

* In my third communication at the Biological Society, I said that both the intense pain each injection has caused me and the inflammation it has produced would be notably diminished if the liquid employed were more diluted. The three cases of Dr. Variot have proved the exactitude of my statement. He made use of a much larger amount of water, and his patients had to suffer no very great pain and no inflammation.

† The paper of Dr. Variot and my remarks upon it have appeared in the "Comptes Rendus de la Societe de Biologie," No. 26, 5 Juillet, 1889, pp. 451 and 454.

‡ Since writing the above I have received a letter from Dr. Variot announcing that, after injecting the liquid drawn from the testicles into these two individuals, he has obtained the same strengthening effects I have myself experienced.

§ It may be well to add that there are good reasons to think that subcutaneous injections of a fluid obtained by crushing ovaries just extracted from young or adult animals, and mixed with a certain amount of water, would act on old women in a manner analogous to that of the solution extracted from the testicles injected into old men.

TOBACCO SMOKING AS A SAFEGUARD AGAINST INFECTIOUS DISEASE.

AT a recent meeting of the Vienna *Medicinisches Doctoren Collegium* an interesting discussion on tobacco smoke and diphtheria took place, the impulse toward the discussion having been given by a communication on this subject by Dr. S. Hajek, of Vienna. Induced by the experiments of Tassinari, of Pisa, on the destructive influence of tobacco smoke on bacteria, Dr. Hajek had made researches in the *Stadtphysikat* of Vienna, in order to determine the proportion of the cases of diphtheria among smokers and among non-smokers. For this purpose he had collected data for the preceding three years, considering all individuals of the male sex upward of twenty-two years of age as smokers.

Among all these, three thousand persons had had diphtheria during that time, and the proportion of the smokers to the non-smokers was, on an average, 1 to 2·8. Dr. Hajek, moreover, said that he would discuss this subject more exhaustively in a work to be published shortly, as he was of the opinion that in bacteriological and hygienic questions a certain importance, though a minor one, should be given to statistics. The speaker directed attention to a statistical work by Professor Oser bearing on this subject of the proportion of cases of diseases in men and in women in a certain epidemic of exanthematous typhus. Oser had observed that three times as many women as men were affected by the disease. The explanation of this difference was considered to be that men, in most cases, lived for only a few hours in insanitary dwellings, and thus became infected less easily than women. This difference ought also to be taken into account in collecting the data for diphtheria. The speaker wished, moreover, to emphasize the difficulty of determining the exact number of smokers. Dr. Neudorfer called attention to the fact that a real destroyer of bacteria, pyridine, was present in tobacco smoke. Dr. Schiff added that in all bacteriological laboratories smoking was forbidden, as the smoke undoubtedly hindered the growth of the cultivated bacteria.

TREATMENT OF STEEL BY HYDRAULIC PRESSURE.

AT the meeting of the Institution of Civil Engineers, Sir George B. Bruce, the president, being in the chair, the paper read was on "The Treatment of Steel by Hydraulic Pressure, and the Plant employed for the Purpose," by Mr. William Henry Greenwood, M. Inst. C.E. Attention was directed in the paper to the presence of blowholes in steel ingots, also to their origin, and to the various methods proposed for the production of sound ingots; but the author treated, more especially, of the method, the effect, the advantages, and the development of fluid compression, as typified in the plant and 10,000 ton press erected by him at the Abouchoff Works, St. Petersburg. It was assumed that molten Bessemer, open hearth, or crucible steel possessed the quality of occluding a considerable volume of gases, especially hydrogen and nitrogen, derived all or in part from the products of combustion in the furnace, or from other sources; and that, under ordinary conditions as to pressure, such occluded gases were more or less completely evolved at the moment when the particles of metal changed from the liquid to the solid state, and were thus imprisoned within the ingot in the form of bubbles of various forms and dimensions.

A second source of unsoundness arose from the contraction of the metal within the ingot after its outer skin had solidified, producing contraction cavities: and lastly the metal from ingots as usually cast was weak along the surface, owing to the development of a radial acicular structure in the cast metal. The combined effect of these three causes was that ingots of mild steel, such as were used in the construction of ordnance, large engine shafts or other heavy forgings, for cylinder liners, torpedoes, and war material, contained cavities necessitating the rejection of about thirty per cent. from the head or top end of each ingot; while to get rid of the surface honeycombs and weak acicular structure, which caused unclean, seamy, and roaky forgings, an additional ten per cent. to twenty per cent. of metal had to be left for turning and machining to waste. Even after these losses of material the remaining metal was inferior to the same metal after fluid compression.

The method of fluid compression claimed, then, to save the whole of the rejected head or top of the ingot, to reduce to a minimum the amount of metal to be left for turning or machining from the surface of forgings, and to produce for any temper of metal a greater amount of ductility, homogeneity and reliability than was obtainable under the best conditions of casting in open moulds without pressure. The addition of increased proportions of manganese and of silicon did not commend themselves to the author for the classes of steel under consideration; for although promoting solidity of the ingot, they hardened, raised the elastic limit and ultimate tensile strength, but lowered the ductility and general reliability of the metal. Of the mechanical devices for increasing the solidity of steel ingots, the author noted the proposals for the cooling of the outside of the moulds, for agitating the metal during solidification, casting the metal in a vacuum, and the direct application of pressure, by the use of high pressure steam, injection of water, of explosives, of solid carbon dioxide, etc., upon the surface of the fluid steel in closed moulds.

These methods of fluid compression had all failed from mechanical, physical, and practical difficulties in their conduct; and the plan suggested by Sir Henry Bessemer in 1856, but quite independently developed and carried to a successful issue at the works of Sir Joseph Whitworth & Co., and now known as the method for the fluid compression of steel, remained the only one before the public which yielded ingots of mild steel of practically uniform molecular structure, strength, and ductility throughout their whole length. The ordinary cast iron moulds, or wrought iron casings, lined with brick or moulding cement, could not be used when aggregate pressures of thousands of tons were to be exerted upon the surface of the fluid metal; but such moulds were replaced, in the fluid compression process, by built-up steel moulds, lined with suitably grooved cast iron lags, protected by a coating of refractory silicious material.

A loose plate of the diameter of the ingot fitted in the bottom of the mould, and was protected by an upper covering of burnt fireclay segments, and a similar plate was carried upon the top plunger of the press for closing the top of the mould. The paper traced the development of the hydraulic press for the fluid compression of steel, commencing with the erection, in 1866, in the works of Sir Joseph Whitworth & Co., of a 250 ton press, with a 12 inch cylinder, designed more especially for the compression of the metal for steel shells. In this the mould, which was partially filled with metal, was carried in a middle head of the press, whereupon a core, carried upon the top head of the press, was forced into the fluid metal, at the same time closing the mouth of the mould. After this the pressure was applied from below, as in all the subsequent presses. Following this came a much more useful 2,000 ton press, with two columns, and 30 inch hydraulic cylinder. Its columns were secured by nuts to the base or foundation, and upon the upper ends of the columns was carried a fixed head, upon which rested a vertical hydraulic cylinder, whose piston rod was connected to the intermediate or movable head. The intermediate head could thus be raised to any point, and then locked, so as to resist the application of pressure from below.

The locking arrangement consisted of a pair of nuts, each made in halves, and so disposed that, by the

movement of a lever and a system of links, the halves of the nuts could be either brought together or separated. When separated, the head was free to move, but when closed, the nuts embraced the columns and fitted into a series of parallel, slightly undercut V grooves, which were cut as a thread along the upper halves of the length of the columns. In this manner the head was locked or secured against vertical movement under the action of the bottom or pressing cylinder. The metal was cast in the steel mould already described, and the further movements and action of this press were similar to those of the larger Abouchoff press already referred to. The next press, also erected at Manchester, had four steel columns 12 in. in diameter, and was fitted with five pressing cylinders, namely, four 28 in. in diameter, and one 13 in. in diameter, capable of producing, together, a pressure of 8,000 tons. Except for the locking arrangement, which was complicated, but more nearly automatic than that last described, the principle was the same as in the last.

Its columns were, however, screwed with a square screw-thread, and the locking nuts were not split, but could be made to revolve automatically as the head was raised or lowered. The five pressing cylinders were placed on the base of the press, with the small one in the center. The cylinder for lifting and lowering the movable head was carried upon the upper fixed head or table of the press, while the locking of the movable head at any desired height, according to the length of ingot under operation, was effected by four locking nuts, which could be revolved either just clear of the head, or into firm contact with the same. In the latter case the head was locked fast to the columns, and was immovable under the full pressure of the press acting from below; and in the former condition, the head could be freely lifted to any desired point. This 8,000 ton press was placed second by the author's erection, in Russia, of the press upon the lines of the Whitworth patent of 1874. This press had four screwed columns 16 in. in diameter, and one hydraulic pressing cylinder 50 in. in diameter, capable of exerting a gross pressure of 10,000 tons.

For working the press, an accumulator, giving a pressure of 2 tons to the square inch, was employed, to effect the rapid movements of the head of the press, of the lifts, cranes, etc., during the manipulation and transference of the fluid metal from the furnaces to the mould, and of the mould under the press. The mould having been prepared, dried, and warmed, was placed in position on the lift in front of the press, the ladle with metal was run over it, and the metal tapped into the mould. The ladle was then quickly run back from the face of the press, and the mould with its charge was raised until the platform rested on its top stops. A horizontal hydraulic ram then transferred the mould and its carriage to beneath press, after which the ram was withdrawn and all workmen retired. The moving head then descended until the top plunger came fairly into contact with the fluid metal. The head, weighing 50 tons, would continue to descend for a few seconds, after which it was locked in position and the compression completed by admitting the water direct from the pumps to the large pressing cylinder.

During the first few minutes the ingot shortened rapidly, and a considerable volume of gases escaped and burned from the vents around the top and bottom of the mould. The pressing was continued as long as there was any perceptible shortening. The maximum pressures attained ranged from 4 to 12 tons per square inch on the metal, and were maintained for from forty-five minutes to three or four hours, according to the size of ingot and the condition of the metal. The contraction in length during the application of the pressure usually amounted to about 1½ in. to the foot of length. The author then referred to the former practice of casting hollow forms under the press, which, owing to various enumerated difficulties, had been abandoned in favor of the solid ingot both in England and Russia. In the manufacture of trunnions for 6 in. breech-loading guns from unpressed ingots, the practice was to take an ingot of 65 cwt., reject one-third from the top end, and then to make three trunnions from the remainder of the ingot, after which not unfrequently one of the forgings was rejected for unsoundness.

When pressed ingots were taken, however, five trunnions were made from the same ingot, and a rejected forging for faulty metal was unknown. The density of a fluid-compressed ingot as a whole was from 8 per cent. to 12 per cent. higher than an unpressed ingot. The author's experiments upon sound samples of crucible steel containing 0·54 per cent. of carbon gave a specific gravity of 7·8542 for the unpressed metal, as against a mean of 7·8795 for specimens of the same metal after fluid compression.

In order to compare the behavior of the pressed with the unpressed metal, made from similar materials, and in the same manner, the two ingots of 8 tons each were cast of open-hearth steel. The unpressed ingot contained carbon, 0·5 per cent., and manganese, 0·35 per cent.; it was 30·75 in. in diameter, and 82 in. long. The second was a similar ingot, but containing carbon, 0·39 per cent., and manganese, 0·4 per cent.; it measured 70·5 in. in length after fluid compression, or 79 in. as cast; it was 34·25 in. in diameter. A slab of 4·75 in. in thickness, and of the full length and width of the ingot, was obtained from the center of each by parting each ingot longitudinally into three pieces on the planing machine. The surfaces so obtained presented much unsoundness in the unpressed ingot, while the pressed ingot was quite sound on both faces.

The central slab from the pressed ingot was cut up into seven series of test pieces, in such manner that ninety-eight test pieces were prepared from it, but only five series, or seventy test pieces, were obtainable from the unpressed ingot. The center test of each series was taken directly along the axis of the ingot, and test pieces in each series were cut directly across the axis of the ingot; these were intentionally taken from the very worst part of the compressed ingot. Notwithstanding this and that the mean results were taken over the whole length of the pressed ingot, as against the best or lower two-thirds of the unpressed ingot, and also that the test pieces from the pressed ingot were taken over the full diameter of the ingot, while the samples from the unpressed ingot were taken only over 24 in. of the diameter, the outer and unsound 3½ in. at each end of the diameter being rejected after these and other advantageous conditions were allowed, yet the mean results from the pressed ingot over its whole volume were superior in each detail to

	Mean of the Test Pieces cut Longitudinally.			
	Elastic Limit in Tons per Square Inch.	Ultimate Breaking Strength in Tons per Square Inch	Contraction in Area at Point of Fracture.	Elongation in 4 in.
Unpressed ingot.....	11·71	29·18	per cent. 4·41	per cent. 8·76
Pressed "	11·45	29·53	7·90	12·51

	Mean of Test Pieces cut Transversely.			
	Elastic Limit in Tons per Square Inch.	Ultimate Breaking Strength in Tons per Square Inch.	Contraction of Area at Point of Fracture.	Elongation in 4 in.
Unpressed ingot.....	11·43	28·04	per cent. 3·61	per cent. 7·91
Pressed "	12·28	30·07	7·57	12·74

those from the five series of tests from the unpressed ingot, and especially in the contraction of area and elongation before fracture. The results, as derived from the test pieces cut transversely, compared equally favorably. The test pieces were cylindrical, with collars, and the metal was not subjected to any hammering, annealing, hardening, or other treatment, except machining, after it came from the ingots.

The pressed ingot gave its highest breaking strength in the upper sections, while the unpressed ingot, on the contrary, was at its best toward the bottom, and showed a rapid falling away at points exceeding one half of the length of the ingot from the lower end; and while the elongation amounted to 12·4 per cent. in the lowermost of the tests from the unpressed ingot, it fell rapidly away toward the upper part, so that in the fifth series the mean elongation was only 2·02 per cent. The pressed ingot, on the other hand, gave a mean elongation at its lowest point of 13·7 per cent., decreasing somewhat in the succeeding series; but still, at the very top of the ingot, the elongation was represented by 11·63 per cent. The figures further indicated that, in the unpressed (where sound) and also in the fluid-compressed ingots, the mean value of the elastic limit, as also of the ultimate breaking strength of the material, was slightly greater in the metal toward the outer boundary of the ingot, and tended to decrease toward the center.

In the sound portion of the unpressed ingot the mean figure for ductility was much the same, 8 per cent. at all radial distances; but with the compressed ingot there was a decided superiority in this respect as the outer boundary was approached, the figures being 8 per cent. at the center and 17·61 per cent. at the circumference; but the center approached the high figure of the outer circumference exactly as the pressure applied had been of higher intensity and more effectively applied. The author inferred, from the figures adduced, that under mechanical tests the metal from the top or any other vertical section of a pressed ingot was, at least, equal to the unpressed ingot after one-third or upward of such ingot had been cut off or rejected; that the weakest part of the pressed ingot was along the axis, where the pressure had been least effective; but that this weakness, as compared with the outer layers, arose from insufficient pressure, and could be localized; so that, for hollow shafts, tubes, hoops, cylinders, and the like, where the center was finally removed, either by boring or punching out, it was unnecessary to proceed to the higher pressures, required to insure absolute solidity and uniformity over all parts of any section. With unpressed ingots, on the other hand, the unsoundness was irregularly distributed, and not capable of such localization, even in the lower end of the ingot. The paper concluded by referring to the effects of annealing and forging upon pressed steel, with tests from various gun forgings, and of shell metal in its soft and hardened states, as also after firing at armor plates.

THE CALORIFIC VALUE OF FUELS.

By MARCUS A. JONES.

THE object of this communication is to compare the chemical composition of the most important varieties of fuel, and to exemplify the principles upon which their heating power may be calculated from the results furnished by the analysis of the fuel.

All varieties of ordinary fuel, of course, contain a large proportion of carbon always accompanied by hydrogen and oxygen and sometimes by small proportion of nitrogen and sulphur. Certain mineral substances are also contained in all solid fuels, and compose the ash when the fuel is burnt.

For all practical purposes it may be stated that the amount of heat generated by the combustion of a given weight of fuel depends upon the weights of carbon and hydrogen respectively which enter into combination with the oxygen of the air in the act of combustion of the fuel. It has been ascertained by experiment that 1 grain of carbon (in the form in which it exists in wood charcoal), when combining with oxygen to form carbonic acid, produces a quantity of heat which is capable of raising 8,080 grains of water from 0° to 1° of Centigrade thermometer. This is usually expressed by saying that the *calorific value* of carbon is 8,080, or that carbon produces 8,080 *units of heat* during its combustion to carbonic acid. If the fuel, therefore, consisted of pure carbon, it would be merely necessary to multiply its weight by 8,080 to ascertain its calorific value.

One grain of hydrogen during its conversion into water by combustion evolves heat enough to raise 34,400 grains of water from 0° C. to 1° C., so that *calorific value of hydrogen* is 34,400.

If the fuel consisted of carbon and hydrogen only, its calorific value would be calculated by multiplying the weight of carbon in one grain of the fuel by 8,080 and that of the hydrogen by 34,400, when the sum of the products would represent the calorific value. But if the fuel contains oxygen already combined with it, the calorific value will be diminished, since this oxygen will represent the consumption of a part of the combustion without generating heat, because it already exists in a state of combustion with the carbon and hydrogen of the fuel.

For example, 1 grain of wood contains 0·5 grain of carbon, 0·06 of hydrogen, and 0·44 of oxygen. Now oxygen combines with one-eighth of its weight of hydrogen to form water, so that the 0·44 grain of oxygen will convert 0·44 ÷ 8 = 0·055 of the hydrogen into water, without evolution of available heat, leaving only 0·005 available for the production of heat. The calorific value of the wood, therefore, would be represented by the sum of 0·005 × 34,400 (= 172) and 0·5 × 8,080 (= 4,040), which would amount to 4,212, or 1 grain of wood should raise 4,212 grains of water from 0° C. to 1° C.

These considerations lead to the following *general formula for calculating the calorific value of a fuel* containing carbon, hydrogen, and oxygen when C, H, and O respectively represent the carbon, hydrogen, and oxygen in one grain of fuel.

The calorific value (or number of grains of water which might be heated by the one grain fuel from 0° C. to 1° C. = 8,080 C + 34,400 $(H - \frac{O}{8})$, or 8,080 C + 34,400 H − 4,300 O. The calorific value of a fuel, as determined by experiment, is generally less than would be calculated from its chemical composition, in consequence of the absorption of a certain amount of heat attending the chemical decomposition of the fuel. In the case of compound of carbon and hydrogen it has been observed that, even when they have the same composition in 100 parts, they have not of necessity the same calorific value, the latter being affected by the difference in the arrangement of the component particles of the compound, which causes a difference in the quantity of heat absorbed during its decomposition. Thus olefiant gas (C_2H_4) and cetylene ($C_{16}H_{32}$) have the same percentage composition, and their calculated calorific values would be identical, but the former is found to produce 11,858 units of heat and the latter only 11,055. As a general rule, however, it is found that the calorific values of the hydrocarbons which contain a multiple of CH_2 agree more nearly with the calculated numbers than do those hydrocarbons which belong to the marsh gas series.

It must be remembered that the calorific value of a fuel represents the actual amount of heat a given weight is capable of producing, and is entirely independent of the manner in which the fuel is burnt. Thus a hundred pounds of coal will produce precisely the same amount of heat in an ordinary grate that it will in a blast furnace, though in the former case the fire will scarcely melt copper, in the latter it will melt steel. The difference resides in the *temperature* or *calorific intensity* of the two fires. Through the blast furnace a rapid draught of air is maintained, and a much greater weight of atmospheric oxygen is brought in contact with the fuel in a given time, so that *in that time* a greater weight of fuel will be consumed and more heat produced.

Hence, the fire will have a higher temperature, for the temperature represents, not the quantity of heat present in a given mass of matter, but the intensity or extent to which that heat is accumulated at any particular point. In the case of the blast furnace cited, a further advantage is gained from the circumstance that the rapid draught of air allows a given weight of fuel to be consumed in a smaller space, and, of course, the smaller the area over which a given quantity of heat is distributed, the higher the temperature in that area (as in the burning or sun glass).

For all steam purposes it is the *calorific value* which chiefly concerns us. But the case is different when metal is to be melted or chemical changes to be brought about by the application of very high temperature, for it is then the *calorific intensity* or actual temperature of the burning mass that has to be considered.

No trustworthy method has yet been devised for determining by direct experiment the calorific intensity of fuel, and it is therefore ascertained by calculating from the calorific value.

Let it be required to calculate calorific intensity or actual temperature of carbon burning in pure oxygen gas: 12 grains of carbon combine with 32 grains of oxygen, producing 44 grains of carbonic acid gas. Hence 1 grain of carbon combines with 2·67 grains of oxygen, producing 3·67 grains of carbonic acid gas. We have seen before that 1 grain of carbon evolves 8,080 units of heat, or is capable of raising 8,080 grains of water from 0° to 1° C., or, on the supposition that the water would bear such an elevation of temperature, the 1 grain of carbon would raise 1 grain of water from 0° C. to 8,080° C.

If the *specific heat* or the heat required to raise 1 grain of carbonic acid gas were the same as that of water, 8,080°÷3·67 would represent the temperature to which the 3·67 grains of carbonic acid would be raised, and the temperature to which the solid carbon producing it would be raised in the act of combustion, but the specific heat of carbonic acid gas is only 0·2163; so that a given amount of heat would raise 1 grain of carbonic acid to nearly five times as high a temperature as that to which it would raise 1 grain of water. Dividing 8,080 units of heat (available for raising the temperature of the carbonic acid) by 0·2163, the quantity of heat required to raise 1 grain of carbonic acid 1°, we have 37·355 for the number of degrees through which 1 grain of carbonic acid might be raised by the combustion of 1 grain of carbon. But there are 3·67 grains of carbonic acid formed by the combustion, so that the above number of degrees must be divided by 3·67 in order to obtain the actual temperature of the carbonic acid at the instant of its production; that is, the temperature of the burning mass.

The *calorific intensity* of carbon burning in pure oxygen is therefore (37·355° C. ÷3·67=) 10·178° C., or 18·352° F. But if the carbon is burnt in the air, the temperature will be far lower, because the nitrogen of the air will absorb a part of the heat to which it contributed nothing. The 2·67 grains of oxygen required to burn 1 grain of carbon would be mixed in air with 8·93 grains of nitrogen, so that the 8,080 units of heat would be distributed over 3·67 grains of carbonic acid and 8·93 grains of nitrogen. Since the specific heat of carbonic acid is 0·2163, the product of 3·67×0·2163 (or 0·794) represents the quantity of heat required to raise the 3·67 grains of carbonic acid from 0° to 1° C.

The specific heat of nitrogen is 0·2438, hence 8·93× 0·2438 (or 2·177) represents the quantity of heat required to raise the 8·93 grains of atmospheric nitrogen from 0° to 1° C. Adding these products, we find that 0·794+2·177 =2·971 represents the quantity of heat required to raise both the nitrogen and carbonic acid from 0° to 1° C.

Dividing the 8,080 by 2·971, we obtain 2,720° C.=4,928°

F. for the number of degrees through which these gases would be raised in the combustion, *i. e.*, for the calorific intensity of carbon burning in air. If the air be heated, the amount of this heat will be whatever that increase may be. This could be farther increased by compact fuel and diminished area of combustion, so that it might be stated without serious error that a temperature of 5,528° F. may be produced by this means.

In calculating the calorific intensity of hydrogen burning in air, from its calorific value, it must be remembered that in the experimental determination of the latter number, the steam produced in the combustion was condensed to the liquid form, so that its latent heat was added to the number representing the calorific value of the hydrogen; but the latent heat of the steam must be *deducted* in calculating the calorific intensity, because the steam in that case goes off from the burning mass and carries its latent heat with it.

One grain of hydrogen burning in air combines with 8 grains of oxygen, producing 9 grains of steam, leaving 26·77 grains of atmospheric nitrogen and evolving 34,400 units of heat. It has been experimentally determined that the latent heat of steam is 537° C., that is, 1 grain of water in becoming steam absorbs 537 units of heat (or as much heat as would raise 537 grains of water from 0° to 1° C.) without rising in temperature as indicated by the thermometer. The 9 grains of water produced by the combustion of one grain of hydrogen will absorb or render latent $537 \times 9 = 4{,}833$ units of heat. Deducting this quantity from the 34,400 units evolved in the combustion of one grain of hydrogen, there remains 29,567 units of heat available for raising the temperature of the 9 grains of steam and 26·77 grains of amospheric nitrogen. The specific heat of steam being 0·480, the number $(0{\cdot}480 \times 9 =)$ 4·32 represents the quantity of heat required to raise the 9 grains of steam through 1° C., and the specific heat of nitrogen (0·2438) multiplied by its weight (26·77 grains) gives 6·56 units of heat required to raise the 26·77 grains of nitrogen through 1° C.; by dividing the available heat (29·567 units) by the joint quantities required to raise the steam and nitrogen through 1° C. (4·32+6·53=10·85), we obtain the number 2,725° C. (4,937° F.) for the calorific intensity of hydrogen burning in open air.

The method of calculating the calorific intensity of a fuel composed of carbon, hydrogen, and oxygen can now be easily followed. Let C and H respectively represent the weights of carbon and hydrogen in 1 grain of fuel, and O that of the oxygen.

Then $\frac{O}{8}$ = weight of hydrogen required to convert the oxygen into water, and $H - \frac{O}{8}$ represents the hydrogen which is available for the production of heat; $8{,}080\ C + 34{,}400\ (H - \frac{O}{8})$ represents the calorific value in °C = $8{,}080\ C + 34{,}400\ H - 4{,}300\ O$, 2·67 = atmospheric oxygen consumed by the carbon, $8\ (H - \frac{O}{8})$ or $H - O =$ atmospheric oxygen consumed by the hydrogen available as fuel; $334\ (2{\cdot}67\ C + 8\ H - O) =$ atmospheric nitrogen = $8{\cdot}92\ C + 26{\cdot}72\ H - 3{\cdot}34\ O$.

Multiplying this by the specific heat of nitrogen, 0·2438, we obtain $2{\cdot}17\ C + 6{\cdot}51\ H - 0{\cdot}81\ O$ for the heat required to raise the nitrogen through 1° C.; $0{\cdot}794\ C$ represents the quantity of heat required to raise the carbonic acid through 1° C., and 4·32 H is the heat required to raise the steam through 1°. Accordingly, the available heat, $8{,}080\ C + 34{\cdot}40\ H - 43{,}000\ O$, must be divided by $0{\cdot}794\ C + 4{\cdot}32\ H + (2{\cdot}17\ C + 6{\cdot}51\ H - 0{\cdot}81\ O)$, or $2{\cdot}96\ C + 10{\cdot}83\ H - 0{\cdot}81\ O$, in order to obtain the calorific intensity. Hence formula

$$\frac{8{,}080\ C + 34{,}400\ H - 4{,}300\ O}{2{\cdot}96\ C + 10{\cdot}83\ H - 0{\cdot}81\ O}$$

represents the calorific intensity of a fuel composed of carbon, hydrogen, and oxygen.

The actual calorific intensity of a fuel is not so high as it should be according to theory, because part of the carbon and hydrogen is converted into gas by destructive distillation of the fuel, and this gas is not actually *burnt in the fire*, so that its calorific intensity is not added to that of the burning, solid mass. Again a portion of the carbon is converted into caloric oxide (CO), especially if the supply of air be imperfect, and much less heat is produced than if converted into carbonic acid.

Although it is true that this carbonic oxide may be consumed above the fire by supplying air to it, the heat thus produced does not increase the calorific intensity of the fire itself.

For instance, one grain of carbon furnishes 2·33 grains of carbonic oxide, thus 2 33 grains of carbonic oxide evolve in their combustion 5,599 units of heat. But if the one grain of carbon had been converted at once into carbonic acid, it would have evolved 8,080 heat units, so that $8{,}080 - 5{,}599 = 2{,}481$ heat units lost *in the fire* by imperfect supply of air.

In all ordinary fires and furnaces a large amount of heat is wasted in the current of heated productions of combustion escaping from the chimney; of course a portion of this heat is necessary in order to produce the draught. In boiler furnaces it is found that for this purpose the temperature of the air escaping from the chimney must not be lower than from 500° to 600° F.

If the fuel could be consumed by supplying only so much air as contains the required quantity of oxygen, a great saving might be effected, but in practice about twice the calculated quantity must be supplied in order to remove the products of combustion with sufficient repidity.

MARCUS A. JONES.

Frankfort, Ky.

SEA BOILER DEPOSITS.

"THE Chemistry of Marine Boiler Incrustations" was the subject of a paper read by Professor Vivian B. Lewes, F.C.S., etc., which was read at the recent meeting of the Institute of Naval Architects. There are some points in the paper worth mentioning in these pages. First, as to the solid constituents of sea water. These are sodium chloride (2·5 per cent.), calcium sulphate and carbonate, and magnesium carbonate, chloride, and sulphate. The normal specific gravity of sea water is 1·027. On concentration to sp. gr. 1·050, the only solid constituents which are deposited are the two carbonates, and these, with calcium sulphate, entirely disappear when the water reaches a density of 1·225, the sodium chloride meanwhile having risen to about 24 per cent., and the magnesium chloride and sulphate having also increased in the same ratio. Strange to say, however, the deposit does not have the theoretical composition—a fact due to the influence of the high pressure of the boilers. An incrustation showed 90·84 per cent. of calcium sulphate, 0·75 per cent. of magnesium hydrate, 1·11 per cent. of copper carbonate, together with silica, iron, alumina, etc. The magnesium hydrate is supposed to be formed by double decomposition of the magnesium chloride and calcium carbonate. This explains why calcium carbonate is never found in the deposit. The copper deposit is supposed to arise from the action of the distilled water from the surface upon the brass and copper tubes of the boiler. The copper deposits are also only found on the under side of the scale that is in contact with the metal of the boiler tubes, showing that in all probability it had been deposited, as suggested, from the water in the boiler, and in contact with the iron would set up galvanic action and tend to produce pitting. After discussing the various suggestions regarding the prevention of boiler incrustation, Professor Lewes arrives at the conclusion that the best plan is to treat every ton of sea water with 40 lb. of soda crystals, then heat up in a separate apparatus by passing through the solution superheated steam. The result is that magnesium and calcium carbonates are precipitated quickly, and the water, after being forced through filtering frames into the hot well of the boiler, is ready for use.

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